DEPARTMENTS OF VETERANS AFFAIRS AND HOUSING AND URBAN DEVELOPMENT, AND INDEPENDENT AGENCIES APPROPRIATIONS FOR 1991

HEARINGS

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

SUBCOMMITTEE ON VA, HUD, AND INDEPENDENT AGENCIES

BOB TRAXLER, Michigan, *Chairman*

LOUIS STOKES, Ohio
LINDY (MRS. HALE) BOGGS, Louisiana
ALAN B. MOLLOHAN, West Virginia
JIM CHAPMAN, Texas
CHESTER G. ATKINS, Massachusetts

BILL GREEN, New York
LAWRENCE COUGHLIN, Pennsylvania
JERRY LEWIS, California

RICHARD N. MALOW and PAUL E. THOMSON, *Staff Assistants*

PART 2

Page
National Science Foundation 1
Office of Science and Technology Policy 551

Printed for the use of the Committee on Appropriations

U.S. GOVERNMENT PRINTING OFFICE
28-691 O WASHINGTON : 1990

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

H181-32

COMMITTEE ON APPROPRIATIONS

JAMIE L. WHITTEN, Mississippi, *Chairman*

WILLIAM H. NATCHER, Kentucky
NEAL SMITH, Iowa
SIDNEY R. YATES, Illinois
DAVID R. OBEY, Wisconsin
EDWARD R. ROYBAL, California
LOUIS STOKES, Ohio
TOM BEVILL, Alabama
BILL ALEXANDER, Arkansas
JOHN P. MURTHA, Pennsylvania
BOB TRAXLER, Michigan
JOSEPH D. EARLY, Massachusetts
CHARLES WILSON, Texas
LINDY (MRS. HALE) BOGGS, Louisiana
NORMAN D. DICKS, Washington
MATTHEW F. McHUGH, New York
WILLIAM LEHMAN, Florida
MARTIN OLAV SABO, Minnesota
JULIAN C. DIXON, California
VIC FAZIO, California
W. G. (BILL) HEFNER, North Carolina
LES AuCOIN, Oregon
DANIEL K. AKAKA, Hawaii
WES WATKINS, Oklahoma
WILLIAM H. GRAY III, Pennsylvania
BERNARD J. DWYER, New Jersey
STENY H. HOYER, Maryland
BOB CARR, Michigan
ROBERT J. MRAZEK, New York
RICHARD J. DURBIN, Illinois
RONALD D. COLEMAN, Texas
ALAN B. MOLLOHAN, West Virginia
LINDSAY THOMAS, Georgia
CHESTER G. ATKINS, Massachusetts
JIM CHAPMAN, Texas

SILVIO O. CONTE, Massachusetts
JOSEPH M. McDADE, Pennsylvania
JOHN T. MYERS, Indiana
CLARENCE E. MILLER, Ohio
LAWRENCE COUGHLIN, Pennsylvania
C. W. BILL YOUNG, Florida
RALPH REGULA, Ohio
VIRGINIA SMITH, Nebraska
CARL D. PURSELL, Michigan
MICKEY EDWARDS, Oklahoma
BOB LIVINGSTON, Louisiana
BILL GREEN, New York
JERRY LEWIS, California
JOHN EDWARD PORTER, Illinois
HAROLD ROGERS, Kentucky
JOE SKEEN, New Mexico
FRANK R. WOLF, Virginia
BILL LOWERY, California
VIN WEBER, Minnesota
TOM DeLAY, Texas
JIM KOLBE, Arizona
DEAN A. GALLO, New Jersey

FREDERICK G. MOHRMAN, *Clerk and Staff Director*

DEPARTMENTS OF VETERANS AFFAIRS AND HOUSING AND URBAN DEVELOPMENT, AND INDEPENDENT AGENCIES APPROPRIATIONS FOR 1991

TUESDAY, FEBRUARY 27, 1990.

NATIONAL SCIENCE FOUNDATION

WITNESSES

ERICH BLOCH, DIRECTOR, NATIONAL SCIENCE FOUNDATION

MARY GOOD, CHAIR, NATIONAL SCIENCE BOARD

MARY CLUTTER, ASSISTANT DIRECTOR FOR BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

WILLIAM WULF, ASSISTANT DIRECTOR FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

JOHN WHITE, ASSISTANT DIRECTOR FOR ENGINEERING

ROBERT CORELL, ASSISTANT DIRECTOR FOR GEOSCIENCES

KENT WILSON, ACTING ASSISTANT DIRECTOR FOR MATHEMATICAL AND PHYSICAL SCIENCES

RICHARD GREEN, DIRECTOR, OFFICE OF RESEARCH FACILITIES MODERNIZATION

PETER WILKNISS, DIRECTOR, DIVISION OF POLAR PROGRAMS

BASSAM SHAKHASHIRI, ASSISTANT DIRECTOR FOR SCIENCE AND ENGINEERING EDUCATION

LINDA SUNDRO, INSPECTOR GENERAL

JEFF FENSTERMACHER, ASSISTANT DIRECTOR FOR ADMINISTRATION

SANDRA TOYE, CONTROLLER

RAYMOND E. BYE, JR., DIRECTOR, OFFICE OF LEGISLATIVE AND PUBLIC AFFAIRS

Mr. TRAXLER. I want to say hello to every one from NSF. It is indeed a pleasure to have you all back.

We will try and make this as painless as possible. We would like to begin the hearings, and again, I want to welcome representatives from the National Science Foundation, Erich Bloch, the Director, of course, and the fine staff that he has.

We would like at this point in time to insert in the record the numbers for Research and Related Activities, the U.S. Antarctic Program, Science and Engineering Education, and the total FTE.

[The information follows:]

NATIONAL SCIENCE FOUNDATION

[In thousands of dollars]

	1989 actual	1990 enacted	1991 request	Difference
Research and related activities	1,583,681	1,725,101	1,954,000	+228,899
U.S. Antarctic Program	131,069	151,682	175,000	+23,318
Science and engineering education	171,127	204,265	251,000	+46,735
Office of Inspector General	0	2,560	3,000	+440
Total, NSF	1,685,877	2,083,608	2,383,000	+299,392
FTE	1,171	1,220	1,252	+32

MR. BLOCH'S TENURE AT NSF

Mr. **Traxler**. We note that Erich, you are completing a six-year term, and in my judgment, these years have really been the high mark of the National Science Foundation, not only in terms of the budgets that were submitted, the presidential budgets submitted to this subcommittee, but I think in terms of leadership that you have provided for the National Science Foundation.

And if the President will listen to my voice, he will reappoint you. We wish you well.

We want to especially express the gratitude on the part of the subcommittee for the relationship that we have had with you and the agency personnel over these years.

I think it has been a very cordial one, but more importantly, I think it's been a very frank one.

Nobody that comes before this subcommittee better represents the agency that they are responsible for, and nobody has a better sense of the national purpose and where this Nation ought to go in terms of science and science education and technology that you have.

And nobody, I think, articulates it as well as you do. You have served this Nation well. And I say that wholeheartedly, honestly and frankly. I am very proud to have been associated with you in your capacity. And I look forward to six more years.

Mrs. **Boggs**. Will the gentleman yield?

Mr. **Traxler**. If you please.

Mrs. **Boggs**. I would like to associate myself with the remarks of the Chairman.

Mr. **Lewis**. Be very careful.

FISCAL YEAR 1991 BUDGET REQUEST

Mr. **Traxler**. You did an end run there. I didn't see you.

Well, the National Science Foundation 1991 budget request represents an increase of $300 million or 14.4 percent increase over 1990. That is roughly the same percentage increase requested in 1990 over 1989.

As you know, we were able to provide less than half of that requested increase last year, to our embarrassment. I know that you were disappointed in our 1990 results, but I wonder—if I may speak for the subcommittee and the staff to tell you that we made some heroic efforts under the circumstances.

We did inventive accounting, and creative financing. We didn't make friends with the Budget Committee, budget types in the Congress or elsewhere in this town. They thought we were pushy, budget busters, and a whole host of other things that we probably richly deserved.

We have had excellent requests in the President's budget for 1991. This subcommittee does very well by the President's request when you total them up, and for that we are appreciative.

However, they are only going to be as good as the 302B allocation, and I am a bit pessimistic on that point. Our 302B fell substantially short of what the actual requirements were of this subcommittee to fund the agencies in this jurisdiction.

We used those accounting gimmicks. I would feel more comfortable about the coming budget year if I knew that they would be available to us again, but as somebody at OMB said, the game's up, Traxler; we are on to you.

They're working mightily to place off the table many of the things we were able to do last year. And the staff's ingenuity and genius in creating finances, may be stimied.

So we are happy to see the President's request. We think it's justified. We think it's in the national interests, but we also wish to put the agencies on notice that we are totally dependent on our 302B allocation. That is the real game in town.

If nobody knows that; we are not going to tell them. But just be aware of it.

And Erich, we would be very pleased to take your statement at this time.

Mr. BLOCH. Thank you, Mr. Chairman, and I appreciate your kind remarks. We all appreciate what you call the heroic effort that it was to produce our 1990 budget. We are making an effort, an heroic effort to use that money wisely and appropriately.

INTRODUCTION OF PERSONS SEATED AT THE TABLE

Before I start, I would like to introduce two or three people that are not around the table here. You don't provide a big enough table for us.

Mr. TRAXLER. We've got budget problems.

Mr. BLOCH. I know it's a fight all over, and I will get back to that.

But I would like to introduce Dr. Fred Bernthal, who is right here. He is the Deputy Director designate of the National Science Foundation, not confirmed yet by the Senate, but we hope that will happen very soon.

He has a very distinguished career; he is a scientist. He was commissioner at the Nuclear Regulatory Agency, and his present job is in the State Department as Assistant Secretary for Oceans and Environment.

Also I would like to introduce Dr. David Sanchez, who will be the new Assistant Director of MPS, which is a job that has been open for six, seven months now.

David is putting himself out of one job, and inserting himself into another job. He will be fulltime with the Foundation in June.

And I think another new face around the table is Dr. Luther Williams, the senior scientist of the National Science Foundation.

Mr. TRAXLER. You have been with us before; haven't you?

Mr. BLOCH. He came from our competitors.

So those are the introductions of the other people. We will have a chance to introduce them, many of them later on.

I also want to introduce Linda Sundro, the new Inspector General of the Foundation. As you know, that is a newly created position, and she is serving in that position.

But primarily I want to thank this committee for its support of NSF over the years. NSF is just finishing its 40th year of operation, and we have come a long way, and you have guided us in many ways.

This subcommittee has played a big role in making NSF what it is today, and as a preeminent Federal agency supporting basic research at universities. We are also a preeminent agency in supporting science and engineering education, and we are a preeminent agency for infrastructure support. And we are also charged with taking the pulse of the country.

How well are we doing in science and engineering education in these fields, as well as in basic research? As the importance of new knowledge in the world continues to grow, so does the importance of NSF and its work, and I know this responsibility concerns you as much as it does us.

Mr. Chairman, Dr. Mary Good, who chairs the National Science Board is with us, and with your permission, I would like to ask her to make a few remarks. She and I held a press conference about three weeks ago on the occasion of the release of the Science and Engineering Indicators Report, 1989.

As you know, this is a report that we publish every two years, and it summarizes data on the status of science and engineering in the United States, as well the world. We also have a lot of international comparisons in that publication.

This year, the Board also issued a short statement that summarized their concern with what the data show us about American science and engineering. I would like to ask Dr. Good to summarize those views and to ask that her statement be entered in the record in its entirely.

Mr. TRAXLER. We will be pleased to do so.

Mary, we want to welcome you again. It's nice to have you back. Please proceed.

[The prepared testimony of Dr. Mary Good follows:]

Draft AShinn c:\spchs90\aprp-h91.mg 2-20-90

Remarks
Dr. Mary Good
Chair, National Science Board

House Appropriations Hearings
Washington, D.C.
Tuesday, February 27, 1990

Thank you, Mr. Chairman. The National Science Board statement on "The State of U.S. Science and Engineering" is a companion to the Board's biannual report, Science and Engineering Indicators - 1989, which was released earlier this month. The full report is a careful compilation of statistics on science and engineering in the United States and our major trading partners. We do it every two years, as a reference. Probably all of you are familiar with it.

The NSB statement, however, is a statement of how the Board feels about the statistics. And the short answer is that we find that there is a lot going for us in science, but some real concerns that it may not stay that way.

It is no secret that the world is undergoing political and economic changes more far-reaching than anything we have seen since World War II. On the political side, the shift towards more open democracy and more reliance on free markets in Eastern Europe, and elsewhere is a clear vote of confidence in the basic strength of our system.

The effect of these changes is to reduce substantially the extent to which the world order is based on military confrontation. That is going to allow a change in national emphasis -- allowing us to think first of economic issues. And that is important, for during much of the last forty years we have simply assumed that the economic strength to maintain both our military forces and our standard of living at home would always be there. But we can no longer take this economic strength for granted.

The economic changes we are concerned with are more gradual and thus less dramatic that the political changes. They are also not concentrated in a particular part of the world. The changes in Eastern Europe coincide in time with a strong movement towards unity and new economic strength in Western Europe, and at the same time the Pacific Rim economies are moving ahead strongly. We are all familiar by now with the globalization of trade, markets, and production, with integrated capital markets and international investment.

It is in this context that we look as the State of U.S. Science and Engineering. The improvement in relations between the superpowers provides us an opportunity to readjust the balance in federal R&D -- and indeed the Administration has already shifted the emphasis significantly towards civilian-oriented R&D. That is a very positive sign.

A new focus on economic competitiveness would be important regardless of political and military developments, however. The world is simply getting more competitive. And in this world, no nation can be strong economically without also being strong in science and technology.

Of course the United States *is* strong in science and technology. We have been the leader for more than forty years, and we still are. We have the largest R&D enterprise in the world, and it continues to grow. Employment of scientists and engineers continues to grow more rapidly than general employment. Americans believe in science and technology.

At the same time, the commanding lead that we used to have has diminished substantially. For many years we focussed much of our R&D effort on defense, with the result that Japan and West Germany now put significantly more resources, relative to the size of their economies, into civilian R&D than we do.

Industrial investment in research is not growing as it should. Our universities suffer from obsolete research equipment and outmoded laboratories.

Most of all, our pre-college education systems has been allowed to deteriorate to an alarming degree. We have had frequent reports of how poorly our students do in international comparisons, and we have not seen any major improvements in comparison with other advanced industrial nations.

These are serious problems. They are not all things that the Federal government can fix. Still less are they things that the National Science Board can fix. But we can *draw* attention to these problems, and hope that the American people will begin to *pay* attention.

What should we do? The Board feels that there are six priority areas.

- First, realize that much of the most important research today is large scale, interdisciplinary, and cooperative. Industry and universities have to get used to this.

- Second, improve education. Especially precollege, but also at higher levels. We need more and better teachers, better curricula, and better student support. All of this will cost money.

- Third, we need more scientists and engineers. We have to change the incentives so that more of our best students go this way. That won't be possible without more minorities and women in science and engineering.

- Fourth, we need better support of university basic research. This is the ultimate source of new ideas, new products, progress. It is not enough by itself -- it has to be linked with industry to realize the economic gains -- but we still need to invest in it sufficiently to solve the equipment, facilities, and individual investigator support problems that we have.

o Fifth, we need better cooperation among universities, industry, and government. We are just learning to work together in this country, where competition and arms-length relations between the sectors has been the rule. But today we have all the competition we need from external sources. Internally, we have to work together.

o Finally, we need stronger international cooperation in basic science -- partly to spread the costs of large projects, but more importantly, to draw on good ideas and talent whereever they are. In today's world, the best ideas may be anywhere, and we have to be there if we don't want to miss out.

That is the essence of the Board's message. The Board is concerned, even worried, that we are not doing enough. And while not all of these problems can be addressed by the National Science Foundation, the budget that we have submitted for Fiscal Year 1991 is a good start. That is why we are here today, and why we are asking your support.

DR. GOOD'S OPENING REMARKS

Mrs. **BOGGS.** It's especially nice to have a Louisiana girl on Mardi Gras day.

Dr. **GOOD.** I was going to comment on your Mardi Gras pin for today.

Mr. **TRAXLER.** Please proceed.

Dr. **GOOD.** First of all, I will not read this. I will leave the full text of it for the record.

Mr. **TRAXLER.** Thank you.

SCIENCE AND ENGINEERING INDICATORS

Dr. **GOOD.** But I did just want to make a couple of comments.

The Science and Engineering Indicators Report is a widely used document. The data in there are used to plan lots of other things, in addition to what we do at the NSF. This year, the Board decided that we needed to add a commentary on what the Board thought, what we saw from the position of the National Science Board.

So we issued a very small report called "The State of U.S. Science and Engineering." I am sure all of you have copies. I am not going to go through it.

The reason that we felt it necessary to do that is that the Board feels that we have some concerns today, namely the economic issues that are now on the table, the fact that we have these major international changes going on, particularly in Eastern Europe. Things that are happening which change the whole way we look at defense and the kinds of issues that we have with respect to the Nation's security, which is going to depend more upon economic factors in the future.

And surely in the short term, the issue is whether we are in a position to compete, whether we have the people, and whether we have the programs, and whether we have the will, frankly, to compete, which is a very important issue because we really do see some major problems.

NSB PRIORITY ISSUES

So let me just share with you the priority issues where the Board feels we have to put some effort; and as I said, I have some other comments for the record, but I won't go through those here in detail.

First of all, we do have serious problems. But we understand that they are not all things that the Federal Government can fix. They are not all things the National Science Board or the National Science Foundation can fix.

But what we want to do is to draw attention to those problems in the hope that the American people will pay attention because we believe they are major issues.

Let's talk just a little bit about research, which is the NSF, that—and people production are its major occupation. First we realize that much important research today is large scale, interdisciplinary and cooperative. That is a different mode of doing work.

It does not say that individual investigators are any less important than they have ever been, but it does say that that is the way many new things are getting done, and so industry and the universities have to get used to doing that.

The second is improve education, especially precollege, but also at the higher levels. We need more and better teachers, better curricula, better student support; and unfortunately all of that costs money.

Third, we need more scientists and engineers. We have to change the incentives so that more of our best students go into science and engineering. There was a time in this country when the very best students were in science and engineering. We are finding today that isn't the case.

Mr. **Traxler**. Where are they going? What are they doing?

Dr. **Good**. Interesting enough, they are going into things like finance, accounting.

A personal comment. When people make more money, simply by moving money about, students learn how to do that, too. So we have to get back to the point where it's an appropriate thing to do to create new wealth, not just move what we already have across the chess board.

Mr. **Lewis**. I beg your pardon. Would you say that one more time?

Mr. **Traxler**. So that its heard all the way up to Wall Street.

Dr. **Good**. What I said was that it's time that we reward and make it absolutely the thing that a young, bright kid wants to do, to create new wealth, not just to shuffle what we already have across the table, because we are doing a lot of that at the moment.

But the kids understand that, and so they are going into finance, and they are going into accounting, and they are going into law and those kinds of things which are necessary things but really don't add much to the actual pile of wealth on the table.

We need incentives so that our best students will go into science and engineering where we make new products, and we make them better than anybody else, where we have manufacturing that is better than other people's, because that is where we are going to live or die in the future, we think.

Fourth, we think better support of university basic research is an absolute essential piece of that puzzle. Not the only piece, but a very essential piece. The ultimate source of new ideas, new products, progress, whatever.

That is not enough by itself. We have to link it with the industry to get the economic gains, but we still have to invest sufficiently to solve the equipment, facilities and individual investigator support problems that we have. And they really are very serious today.

We have a lot more good proposals that would really make a difference than we can possibly handle in today's mix.

Fifth, we need better cooperation among the universities, the industry, and the government. I think this is a truly important issue and one that we need everybody to think out.

We are just learning how to work together in this country where competition and arms-length relations between the three sectors has always been the rule.

But today, it's the Board's position that we have all the competition we need from outside the United States, so internally we should find better ways to work together between the universities, the industry and the government.

And finally, we need stronger international cooperation, particularly in basic science, partially to spread the costs of some of the large projects which we would like to do at the cutting edge, but frankly, more importantly, to draw on good ideas and talent, wherever they are, because we have in the past built our science and engineering enterprise to some extent on people who came from other countries and other cultures.

There are very good ideas all over the world today, and we have to understand we have to capture some of those if we are going to be competitive.

Mr. **Traxler**. You are not suggesting we should finance basic research in foreign institutions, are you?

Dr. **Good**. Not necessarily, but [illegible]ould encourage those foreign institutions that benefit by what [illegible]are putting into big things like the SCC and some of the other big instruments, like astronomy facilities. We believe those cost ought to be shared.

And in some cases, I would think, Mr. Chairman, that perhaps we ought to consider, particularly in the real fundamental sciences like astronomy, if we can get access to high quality facilities elsewhere without having to carry the burden for all of that ourselves. Perhaps we should consider funding some outside the United States, as a piece of a bigger pot.

We should surely not fund it on our own, which we have done in the past, but as a piece, with other people's contributions.

Mr. **Traxler**. It's very interesting.

In another area of responsibility, the subcommittee knows that when we have relations with other countries in putting science projects together, somehow or other we always seem to come off second best in those negotiations.

Dr. **Good**. Right.

Mr. **Traxler**. Without referring to the State Department, I don't know why we do, but we do.

Dr. **Good**. Well, you know——

Mr. **Traxler**. They have a problem regulating who they represent.

Dr. **Good**. Let me make a comment about that. I think the time has come when the United States has to represent itself better, and we have to negotiate from a position of strength.

And if you cannot get people to play on a level playing field, walk away.

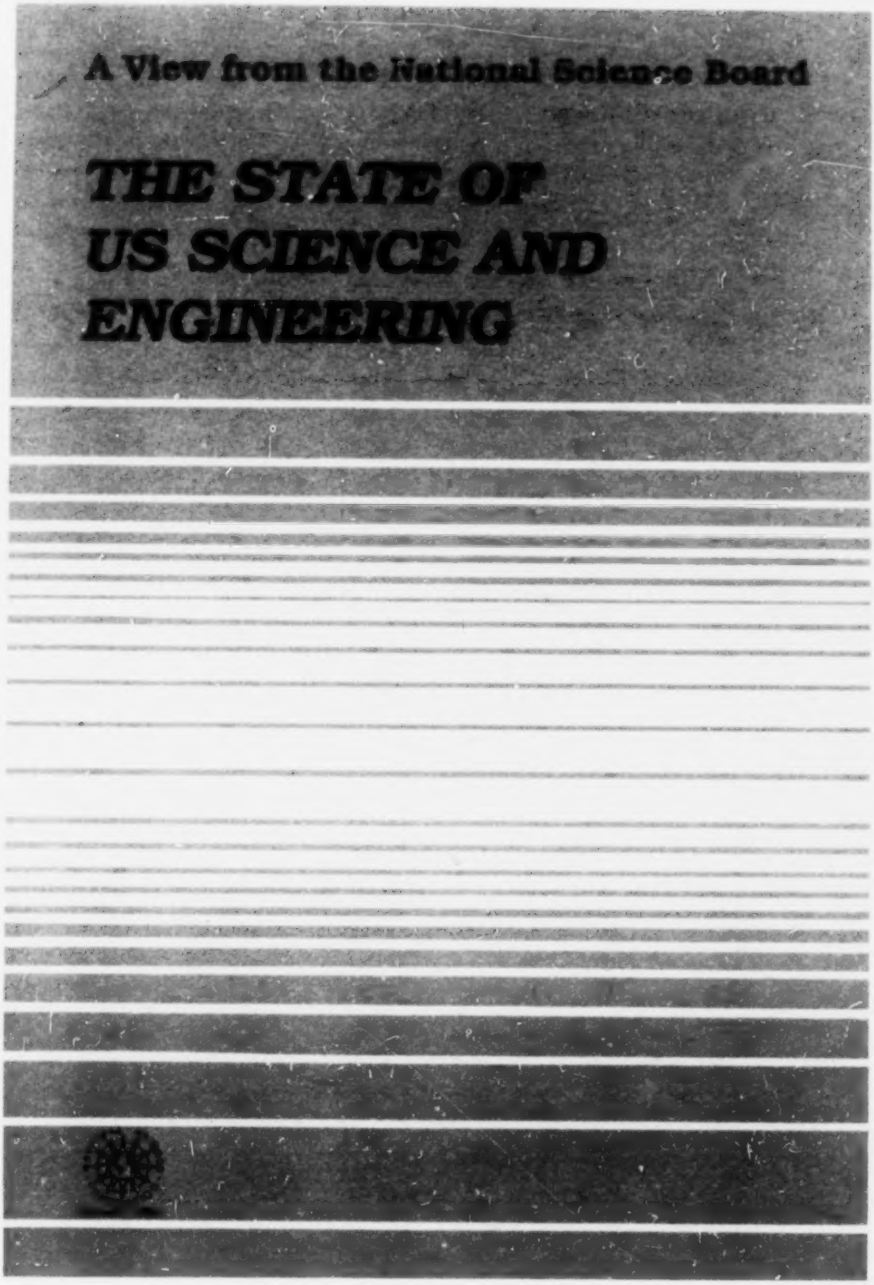
Mr. **Traxler**. Well, you are sure preaching to the church. You know, I have been sitting here for 10 years waiting for somebody to say those things.

Dr. **Good**. But I think it's time, and the industry is beginning to learn. We have negotiated with the Japanese, and we have given a lot away. We have about come to the realization that unless we negotiate in our own best interests, nobody else is going to do that for us, and I think it's time that the country did the same.

Thank you, Mr. Chairman. Those are the comments I would like to make, and I will enter the rest in the record.

Mr. **Traxler**. We appreciate that. It was heartfeltly delivered and very well received on this side of the table, I am sure.

[The information follows:]



A View from the National Science Board

THE STATE OF US SCIENCE AND ENGINEERING

I. Introduction

Every two years the National Science Board publishes factual data on the condition of American science and engineering in **Science and Engineering Indicators** – a widely-used resource in government, industry, and academia.

Accompanying **Science and Engineering Indicators**, the Board in this statement presents its conclusions about the strengths and weaknesses of American science and technology and its recommendations for action.

In sum, American science and engineering are vibrant and productive, although the United States no longer dominates science and technology as it once did. And American education in science, engineering, and mathematics is a national problem that has not yet been effectively addressed.

We need a new national commitment to provide human, financial, and physical resources commensurate with the importance of science and technology to America's future. The solutions will require cooperative action and increased investment by industry and universities, by state and local governments, and by the federal government.

II. The Competitive Context for American Science and Engineering

a. *The Shift to a World Economy*

Until recent decades the U.S. economy was largely isolated from the rest of the world. Our market was the largest in the world. Our companies could prosper without exporting, and technological leadership protected them from imports.

None of this is true any longer. Europe and Japan recovered from World War II. Industrialization has spread rapidly in the third world. Better transport and communications have made world-wide industrial and commercial organizations possible, and competition has made them necessary. World trade has increased seven-fold since 1970; today over two-thirds of the goods we produce must compete against merchandise from abroad.

In this situation an effective science and technology policy must recognize that we are now one competitor among many, no longer uniquely advanced over other countries. Policy must emphasize cooperation among all sectors and ask how best to meet international competition.

b. *The Shift to a Knowledge Economy*

Knowledge has become a critical commodity in the global economy, diminishing the importance of natural resources and low-cost labor. Industries based primarily on knowledge and fast-moving technology, such as computers, semiconductors, synthesized materials and biotechnology, are becoming new basic industries, reducing the relative importance of those based on natural resources.

In the knowledge economy, progress is astonishingly fast. Electronics, semiconductors, and computers have been developing rapidly for thirty years, and show no signs of stopping. Biotechnology is beginning an evolution that may be just as important and just as fast. So is manufacturing technology – a field we have neglected, but our competitors have not.

To compete, new knowledge must be both created and then applied quickly and economically to create new products and processes. Failing this, the economic benefits will be largely lost to others. Innovating faster and more effectively than one's competitor is the key to prosperity.

III. The Status of American Science and Technology

The National Science Board finds many signs of strength in American science and engineering in 1989:

- Our R and D effort remains the largest and strongest in the world.[1]
- Since 1980, the number of Americans employed in science and engineering has risen twice as fast as employment in general.[2]
- We have recognized that women and minorities must be brought into science and engineering in much larger numbers, and begun programs to increase their participation.
- The American public believes in the benefits of science and technology.[3]
- More students are taking high school courses in mathematics and science.[4]
- American graduate education remains the best in the world, with large numbers of foreign students coming here to study.[5]
- At least thirty-eight state governments have set up special agencies to encourage science and technology as a key element of economic development.[6]

Yet the Board also finds many trends that suggest weakness in our national effort in science and technology:

- In international competitions in mathematics and science, American students at the 5th, 9th, and 12th grade levels perform poorly in comparison with industrialized nations and even some third world countries.[7]
- Fewer college freshmen expect to major in technical subjects.[8]
- Too few of our citizens pursue graduate degrees in mathematics, science or engineering.[9]
- Despite much effort and some improvement, the number of minorities and women in science and engineering remains disproportionately small.[10]
- Although twenty years ago the United States had a far larger fraction of its labor force employed in science and engineering than any other country, today a number of our competitors have employment fractions comparable to ours, and are increasing their numbers of scientists and engineers more rapidly than we are.[11]
- Similarly, twenty years ago our rate of investment in R and D, as a fraction of GNP, was far higher than that of any other country. Today Japan and West Germany exceed our rate, and other countries equal it.[12]

- Comparing only civilian-oriented R and D, our rate of investment, as a fraction of GNP, is only about two-thirds that of Japan and West Germany. And civilian-oriented R&D is by far the most important in economic terms.[13]

IV. Necessary actions

We should take action to correct the weaknesses in this mixed picture of the state of American science and technology. What should we do?

First, although the individual investigator remains the mainstay of scientific inquiry, modern science and engineering research is more organized, capital intensive, multidisciplinary and cooperative than in the past. Our universities must adapt to meet this need.

Second, we must dramatically improve precollege and undergraduate education. Only a well educated work force can exploit new knowledge effectively, and only a technically competent population can deal with the political issues that modern technology raises.

- Our schools must put first priority on basic education. Students should be required to take science and mathematics throughout high school.
- We need better science and mathematics teachers, and we need more of them. To get them we must be willing to pay what they are worth.
- Undergraduate science and engineering needs major improvement, especially in areas such as research opportunities and instrumentation.

Third, we must persuade more of our best students to study science and engineering, at both undergraduate and graduate levels. Scientists and engineers are our researchers and teachers. They generate the knowledge that makes technological innovation possible. And in a modern technological society, more people with technical training should be leaders in business, government, and the professions.

Persuading enough qualified people to undertake the rigorous training this requires will be a continuing problem. The number of students of college age will continue to decline until almost the end of the century. A larger proportion of the labor force will be women and minorities, who have historically not been attracted to science and engineering. Only a concerted effort with special programs can meet this challenge.

Part of the answer also must be an expanded program of graduate fellowships and traineeships – sufficient to provide incentives to the best science or engineering students to undertake graduate study. We will face serious shortages of research scientists and engineers if we cannot deal effectively with this problem.

Fourth, we must greatly strengthen university basic research. Universities are the source of most of the fundamental new ideas that drive innovation, and of all new research scientists and engineers.

But the nation has paid insufficient attention to university basic research in the last twenty years. To keep us competitive with other countries, investment in it should keep pace with growth in the high-technology sector of the economy. This will take a cooperative effort involving both the public and private sectors.

- Federal support for academic research and development, as a fraction of GNP, is no higher than it was in 1968.[14] Relative to the size of the high-technology sector of the economy – which depends on it uniquely – university basic research has declined in the last decade. Furthermore, the growth that has occurred has been mainly in the life sciences – important for health and biotechnology but less important for international competitiveness than the physical sciences and engineering.

Fifth, we must develop better cooperation among industry, universities, and governments. Although universities create the new ideas and educate the people, industry turns ideas into products and thus drives economic growth. Research that is not rapidly incorporated into new products and processes fails to achieve its economic potential.

- Bridging the gap between industry and universities is an area in which government can lead. One good idea was the development over the last five years of multi-disciplinary science and engineering centers on university campuses. These centers do basic research in economically important areas, and help educate students in practical industrial problems.

Sixth, we must encourage greater international cooperation and sharing in basic research. This is fundamentally a function of the spread of science and engineering capabilities around the world. We can no longer depend entirely on our own resources to stay ahead.

- Young scientists and engineers must prepare themselves to work in a global environment through study of foreign languages and cultures and experience in foreign research sites.
- In basic research, open communications among researchers in all nations must remain the rule. More active exchange programs can help develop the personal contacts on which such communications depend.
- More international sharing of the costs of expensive research facilities like telescopes is desirable.
- Coordinated use of national facilities such as satellites, ships, and aircraft can increase the effectiveness of large observational programs, especially in the geosciences.
- Increasing economic integration in Europe raises the possibility that cooperative research activities there will become less accessible to American scientists and engineers. Fair reciprocal arrangements for participation in such programs are important. A special effort to strengthen cooperation with Western Europe is thus desirable.
- Adequate protection of intellectual property rights in all countries is a critical need.

V. A Cooperative Effort

The remedies suggested can only be accomplished by a cooperative effort among all concerned sectors.

Although the National Science Foundation is the only agency whose sole responsibility is the health of American science and engineering, many other agencies play important roles in this area. The Board strongly urges all Federal agencies with a mission in this area to address the remedies suggested in a cooperative manner.

Beyond the Federal government, however, industry, the universities, and state governments also have major responsibilities. State governments have been much more active in supporting research in recent years, and have been major forces in bringing industries and universities together in joint projects. And the responsibility of state and local governments for most precollege and undergraduate education means that they must take the lead in addressing those problems.

Industry's interest in having available a well educated workforce, able to deal effectively with modern technology, has led it already to spend substantial sums in support of local education, and its interest in the latest technology has led it into cooperative relations with universities. These trends should be encouraged and expanded wherever possible.

Finally, universities must reach out to industry and to state and local governments in order to develop cooperative programs that address the real needs of these sectors. Through activities of this sort universities can demonstrate anew their importance to our national economic well-being, and ensure that they have the resources necessary to fulfill their historic missions.

1. *Science and Engineering Indicators - 1989*, pp. 3, 96.
2. *Id.* pp. 6, 63-65.
3. *Id.* pp. 170-72.
4. *Id.* pp. 32-33.
5. *Id.* p. 53.
6. *Id.* p. 100.
7. *Id.* pp. 8, 27-31.
8. *Id.* pp. 9, 50-52.
9. *Id.* pp. 10, 53-55.
10. *Id.* pp. 7, 67-69.
11. *Id.* pp. 80-81.
12. *Id.* pp. 3, 96.
13. *Id.* pp. 4, 96.
14. *Science and Engineering Indicators - 1987*, p. 78.

MAJOR THEMES COMPARISON

Mr. **Bloch**. I wonder if I could continue.

I think Dr. Good's comments reflect on some of the problems that we face as a Nation and that many NSF programs address. I will pass over most of these, because you have the details in our budget materials, as well as in my prepared statement.

I will limit myself here in the interest of time to some comments of a more global nature, and I have a few charts which you also have in front of you which will help me do that.

Let me turn to the first of these charts labeled Major Themes Comparison. We have oriented the Foundation's programs in two major themes: Research and Facilities and Education and Human Resources. This chart shows how the relative emphasis on education and human resources in the NSF budget has increased.

In 1982, for instance, as it appears on this chart, we spent less than 3 percent of our budget in the education and human resources area.

Today we are spending about 20 percent, a significant increase.

On the second chart labeled Education and Human Resources, you see a more detailed graph. It shows our education effort has increased since 1982, and I want to focus primarily on the precollege area, as well as on the undergraduate area.

PRECOLLEGE AND UNDERGRADUATE EDUCATION

In both the precollege and undergraduate area, as you go back to 1982 and 1983 time frame, we had very few dollars in that particular effort. And today between the two of them, they comprise a big portion of our education and human resources budget.

So we are not just focusing on graduate education but also on undergraduate and precollege education.

I want to say one thing. It's very important that we look at the total educational pipeline from kindergarten through post graduate education, because in each of these areas, we have major kinds of problems. And we will have major problems unless we address it.

Mrs. **Boggs**. I have been waiting all these years for somebody to say that.

Mr. **Traxler**. It's a good morning we are having.

Mr. **Bloch**. No prompting.

But the big growth obviously, as you can see, is in precollege and undergraduate activities.

If you move to the next chart here, you see the kind of and number of people we are supporting. Our reach has increased a great deal since 1982 as the first year that we are showing a comparison. In terms of high school students, where we had zero in 1982, precollege is the same way, that we have significantly increased the support of these groups through our various programs.

I should also stress, which is not clear from this particular chart, that these programs have a strong component aimed at encouraging more women and minority students to participate in science and engineering.

We have talked about that before, and you know both of these groups a under-represented resource that we need to be cognizant of and make sure that we are taking full advantage of, and that we give them full advantage of the capabilities that we have.

The Foundation has pioneered precollege programs in areas such as teacher training, materials development, and introducing high school students to research and many more programs of this sort.

RESEARCH AND FACILITIES

The second item, as I mentioned before, is research and facilities. It's the mainstay of the Foundation's activities. It always has been and probably always will be. This supports the individual investigator that Dr. Mary Good talked about before, their graduate students, and it also provides the major facilities they need, like telescopes, computers, and ships.

While this remains the most important part of our budget, the relative emphasis has dropped from about 88 percent in 1985 to about 80 percent today.

This decline obviously made room for the increases in education and human resources, but it was only a relative decline. Actual dollars in both of these areas increased.

GROUPS AND CENTERS

During the six years I have been director, we have made some changes in the way we support research, in particular, by an increased emphasis on groups and centers.

And Dr. Mary Good highlighted the importance of multi-discipline research in today's work. I know you are familiar with Engineering Research Centers and with Science and Technology Centers as examples of this approach.

In recent years, we treated groups and centers separately from disciplinary research in our budget presentations because we wanted to focus our institutions and researchers in both universities and industry on the need for multi-disciplinary research and for cooperation among industry, universities and government.

We also wanted to make it clear that some basic research should have priority because of its relevance to the Nation's economic performance. Emphasis on groups and centers increased rapidly in 1985 and 1986, and has held fairly steady since then in our budget as we discussed previously with this committee.

This year, as you know, we have combined centers and groups with disciplinary research into a single research and facilities theme. The reason is that centers and groups support research just as much as grants to individual investigators, only in a different way. I think the initial focus on centers that we needed, has fulfilled its purpose.

Mr. LEWIS. I really hate to interrupt at this point, but I think the Director will continue with his statement, and we might lose the mix of those very important items for consideration and the emphasis that might be placed upon the item that he was talking about relative to preschool education and research at that level.

Mrs. Boggs responded to it as well as having some priority. If you don't mind, I would like to ask a question about that specific area.

Mr. TRAXLER. If the Director can be interrupted.

Mr. BLOCH. Certainly.

PRECOLLEGE SCIENCE AND MATH EDUCATION

Mr. LEWIS. I am fascinated, Mr. Bloch, because in December you released a series of excellent science indicator reports, and with regard to precollege science and math education, the report amplifies the many things that you have been saying to the committee.

You found that a shortage of fully trained elementary science and math teachers persists. The amount of daily classroom time spent teaching science is 30 minutes, for math its 50 minutes.

That pattern hasn't changed very much since 1977. Let me raise a question that may challenge the rhetoric, if you will, relative to the actual dollars.

Is it really a balance of priorities to spend 1.81 billion or 75.9 percent of your budget on economic infrastructure facilities and equipment while devoting only $165 million or 6.9 percent to precollege education activities?

I know that you say there has been some trend up, but that hardly keeps up with inflation. And I am wondering if we cannot do a little better. I am wondering if your rhetoric wouldn't suggest we should do a little better than that.

Mr. BLOCH. Well, as you know presenting a budget is a difficult thing to start off with. We have limitations on us, also, and what you see every year is a compromise to do very different activities and meet different kinds of needs.

And I think the balance that we have struck is one that we think is the right one at this point in time. We have been increasing at a much faster rate our involvement in precollege education in particular.

We have doubled it since 1987 while the Foundation had an increase of 40 to 50 percent in the same time period. We are going to triple SEE by 1993 while we are only doubling the Foundation's budget by 1993. So we intend to put a lot of focus on SEE.

Let me just remind you that we are not the only agency in town that does basic research. I want to talk about that for a minute because one has to look at that very closely.

Neither are we the only agency in town that is supporting education. You know, the Department of Education has a much, much bigger budget than we have for that.

BUDGET FOR PRECOLLEGE EDUCATION

Mr. LEWIS. But let me say, I may have more hope for shift within this agency than in that much larger education agency.

The point I want to raise is that I do not see, and I have listened to the discussion over some years now, a growth in spending to match the reports which emphasized the need for precollege. It would appear that the establishment wants to emphasize the intellectual exercise that takes place at that level, which is interesting and commendable.

Nonetheless, 6.9 percent, or $165 million is a small number relatively, and I am wondering if you are concerned about the trend, whether you anticipate a significant adjustment upward of those percentages in the years ahead?

NSF AS A CATALYST

Mr. **Bloch**. Well, I just mentioned that what I foresee is namely a tripling of the numbers by 1993 over that of 1989.

I certainly see that happening.

We know that our responsibility is primarily as that of the catalyst. Even if you double and triple our precollege budget, we cannot possibly be globaled out.

It's the state's and localities that have to contribute to it seriously and many of our programs are geared to leverage state and local dollars.

So look at us not just as a performer that does everything but look at us as a catalyst, look at us as a generator of dollars that come from other areas and as a magnet to attract support from other areas, because I think that is really our mission.

And that is what we can do in a constructive way, even with a doubled or tripled or quardrupled kind of budget.

Mr. **Lewis**. I don't want to take a lot of time at this point, but I wanted to make that point because it seemed to be appropriate at the moment.

It does appear to me as one thing to ring my hands about the number of kids at college that are interested in math and science. I scratch my head and when I rethink the reality of when they start to get interested in math and science. If we don't get them interested earlier, it doesn't matter what we do at the collegiate.

How we change that pattern of interest at the elementary level is just as important.

Mr. **Bloch**. Mr. Lewis, you are making my speech. I have given that same speech over and over and over. But then in the end, you have to come down to say what is the mission of the Foundation; what our budget is; what our role in life should be; and judge us by how well we are doing. We are performing our role.

Mr. **Traxler**. Thank you, Mr. Lewis.

Mr. **Lewis**. Thank you.

BUDGET REQUEST

Mr. **Traxler**. Thank you, Mr. Bloch, for that interesting exchange. I think it is appropriate at this point, before you continue your remarks, to put in the record some sentences from our report of last year accompanying the bill. As we say in the report, it is interesting to note that in 1988 constant dollars, the total funds available to the Foundation, which were approximately $1.650 billion, are almost identical to the monies made available in 1968.

However, in 1968, expressing it in constant fiscal year 1988 dollars, science and education activities captured approximately $400 million of the total available NSF funds, and that compares with $139,500,000 made available in 1988.

Now, we get much better in 1989, I am pleased to tell you. Hopefully, we will do better in 1991. Between 1968 and 1982, the ratio of science education dollars to total NSF dollars steadily declined, in 1984 virtually no monies were requested for science education.

Please proceed.

Mr. **Bloch**. On that last point, I would really like to have a chance to discuss it during the day.

Mr. **Traxler**. Oh, you will, we are going to spend a lot of time on science education.

Mr. **Bloch**. That relationship between the late 1960s and 1991 is a more complex story than that. But, let me move on now to say a couple of things about research.

INITIATIVES FOR ECONOMIC COMPETITIVENESS

The fourth chart that you have in front of you—this is entitled Initiatives for Economic Competitiveness—shows how we have invested in areas of research that we believe are likely to prove economically and environmentally important in the near term, which means somewhere in the next decade.

Some of this investment has been made through large grants for centers and groups. Those awards are highly visible and have attracted some attention. But much more of this investment has been through individual investigators who believe that these fields promise important breakthroughs to new knowledge.

As this new knowledge becomes available, it will make possible applied research and development activities, mostly in industry, that will provide the economic pay off.

The fifth chart gives us a different message. It is entitled U.S. Academic Research and Development in 1964 Through 1989. It presents a different message about the relation of our need to economic competitiveness, and it is a message that concerns us and should concern this committee.

The chart shows a long-term shift away from reliance on the Department of Defense, including the rise of NSF and especially of NIH. What it also tells us is that there was a major shift in the disciplinary emphasis between 1945 and 1975, away from the physical sciences and engineering and towards the biomedical sciences, because of the overwhelming presence of NIH funding.

The pattern here in the United States is very different, therefore, from other countries. We spend about half of our Federal support for academic research in the biomedical sciences, while the comparable figure for Japan and West Germany is under 30 percent. One very positive result is that our pharmaceutical industry and the biotechnology sector are highly competitive in the world market. Those observations suggest the economic importance of a strong and basic research sector.

But most of our industries depend more on the physical sciences and engineering than on the life sciences. Virtually all the industries that have had difficulty with competitiveness from semiconductors to automobiles fall into this latter category.

There is also a feedback from industry into education with respect to career choices. There has been a sharp fall off in 1987 and 1988 in the number of new bachelors degrees in computer science, mathematics and engineering, the disciplines most directly related to industries that are in trouble economically.

One reason for this has to be that students see, correctly, that these industries may not be the best choice for their careers, and Dr. Mary Good touched on that before.

Funding of research, competitiveness in the market place, and choice of careers are related and they are feeding on each other.

Another major difference between the United States and our competitors is the heavy burden of defense R and D that we carry. The President has already increased the relative emphasis on civilian R and D in the 1991 budget, and also the 1990 budget, to 39 percent, up from a low a few years ago of 31 percent. This is a very constructive move, because our major competitors invest substantially more as a fraction of GNP on civilian oriented R and D than we do.

This committee has an opportunity, because of its role in supporting NSF, to help remedy the competitive disadvantage faced by industrial sectors that depend on the physical science and engineering.

HISTORY OF THE NSF BUDGET

This brings me to the last point; namely, the history of the Foundation's budget over the last 40 years. There was a period of rapid growth, then the long period of stagnation, and then a new period of growth beginning in 1982.

Growth after 1956 depended on the perception of national need that followed Sputnik. In the same way, growth today rests on a belief that the nation needs a stronger science and technology base. This has been repeatedly emphasized, most dramatically by the commitment of both President Reagan and President Bush to double the NSF budget over five years, and most recently in Dr. Bromley's statement to the House Science Committee a few weeks ago.

Despite this welcome emphasis on NSF, however, growth in recent years has not come close to what is needed and recommended by the Administration. Since 1982, the NSF budget has increased roughly 50 percent in real terms. We have made progress towards the five year doubling that the Administration proposed, but have fallen short of the mark in each of the last several years, as my last chart shows.

It also shows the 1991 budget request. We need to do better. I urge you to make this the year in which we begin.

Dr. Good's remarks a few minutes ago touched on very important areas in which our national effort needs to be strengthened.

Just to summarize, better education, especially precollege, more scientists and engineers, or more students that pursue scientific and engineering areas, better support of university basic research, better cooperation among universities, industry and government, and international cooperation are all necessary and vital components.

NSF programs contribute to all of these objectives. I have touched on at least the first four of them already, so I would like to conclude with a few remarks about cooperation, both domestically and on the international level.

DOMESTIC AND INTERNATIONAL COOPERATION

Domestically, cooperation can take many forms. An important element is the economic environment that government creates through such areas as tax policy, and antitrust and the like. These areas lie outside the competence of NSF.

Another important element of cooperation among agencies infrastructure are nationally important research programs. The best example is the U.S. global change research program, which will exceed a billion dollars in 1991 and NSF will roughly double to $103 million in 1991. But more important than these numbers is the process through which the effort is being planned, a cooperative effort among 14 different agencies.

This is the kind of cooperation that we need, and we are pursuing it in other areas as well, such as the joint effort between NSF, DOE, NIH and USDA to map and sequence a plant genome.

At the international level, cooperation is even more important. Modern science and engineering programs are much more likely to be global in scope than in the past, and as a result, they are likely to demand levels of resources, financial, and scientific personnel, that are difficult or impossible for any one nation to support.

A classic example from the past is ocean drilling. It is an international endeavor, with NSF being the lead agency in this country. Another good example is a new initiative, the Laser Interferometer Gravitational Wave Observatory or LIGO.

Our plan is to build two of these facilities in the U.S. and then integrate them with compatible observatories to be built by two different European groups. The result will be a network of four integrated observatories and, obviously, reduce the cost to each nation that participates.

Still another example for 1991 is the 8-meter optical/infrared telescope construction which we are proposing to build in partnership with the U.K. and Canada, one in the northern and one in the southern hemisphere. These will open important new fields of astronomy through their ability to make more precise observations than are now possible, and again, share the burden of the financing.

Mr. Chairman, that concludes my remarks on the major programs of the Foundation for 1991. However, before I close, I have to make a special plea for the administrative budget on which we operate the Foundation, what we call PD and M.

PROGRAM DEVELOPMENT AND MANAGEMENT

When I came to NSF more than five years ago, I immediately set out to reduce the funds spent on administration to the absolute minimum.

From the high point of about 6.3 percent of total funds in 1982, PD and M in the 1991 request is down to 4.3 percent, a significant drop. A major reason is that the Foundation's staff has been reduced to 1195 persons, almost exactly the same as the 1190 persons that were authorized in 1974, despite the fact that the Foundation's budget has more than tripled and the number of proposals and grants has more than doubled since then.

Our programs have multiplied in terms of complexity. We are very proud of our record of efficient, lean management. We have done it by using our resources carefully, by trimming away unnecessary procedures, and by extensive use of computers and related technologies.

But we have gone as far as we can go in this direction. We have had to staff some areas below an efficient level, and we have trimmed such things as travel and training below minimally effective levels. These are not frills or categories of waste. They are absolutely necessary to the prudent management of the public's affairs.

No reasonable large corporation would operate under the restricted conditions that we take for granted. I know it is part of the game to ask for more than is required, because requests will also be reduced. I have refused to play this game either with this committee, with the Congress, or with OMB. Our PD and M request is not inflated. It is what we have to have to do our job.

We need a modest addition to staff, and are asking for 30 additional positions in fiscal year 1991 to pay for them and to provide such things as staff training, new office equipment, telephones, printing, postage and the countless small expenses necessary to run the Foundation. We need every dollar of the PD and M request that we put before you this year.

In summary, Mr. Chairman, NSF has carefully constructed a program for 1991 that responds to the major needs of the country for a strengthened base in science and technology. With your support, we will make progress in important new areas of science and engineering. We will improve the education of our students at all levels, and this budget is a major step in the process of building an American science and engineering enterprise adequate to the needs of the 1990s.

I would ask for this committee's support.

Thank you very much.

[The prepared testimony of Mr. Erich Bloch follows:]

TESTIMONY OF

MR. ERICH BLOCH

DIRECTOR, NATIONAL SCIENCE FOUNDATION

BEFORE THE

SUBCOMMITTEE ON VA-HUD-INDEPENDENT AGENCIES

OF THE

COMMITTEE ON APPROPRIATIONS

UNITED STATES HOUSE OF REPRESENTATIVES

FEBRUARY 27, 1990

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

I am pleased to present for discussion the National Science Foundation's budget request for FY 1991.

As the Foundation enters its fifth decade, it finds itself in a very different research environment today compared to fifty or even twenty years ago. Then, research and education were critical for military security; now, they are vital to our economic competitiveness. Yet, despite these changes, the strength of our research system has been and continues to be our linking of research with education. We train our future researchers at the same time we generate new knowledge and transfer that knowledge to practical uses. Now, as then, NSF plays a vital role in supporting the education of a technical workforce and generating new knowledge. In fact, NSF, outside of medical sciences, plays a major role both in physical science and engineering research.

Our FY 1991 budget request builds on the past strengths of our system, yet responds to current changes and challenges. It provides for $2.38 billion, an increase of 14 percent over FY 1990, reaffirming the Administration's commitment to double the Foundation's budget, and reflecting a long-term commitment to significant growth in education and research in science and engineering. It reflects a strategic framework for a significant and balanced investment in education, the generation of new knowledge, and the transfer of knowledge from producers to users. It is an investment designed to nurture the close relationship between basic research and education in science and engineering and, in so doing, improve productivity and economic competitiveness.

THE CRITICAL ROLE OF EDUCATION AND RESEARCH

Knowledge has become a significant economic resource in a changing global economy. Our economic competitiveness increasingly depends upon the health of our research system which generates this knowledge. In turn, the health and vigor of our research system depends on our national investment in science and engineering education and research.

Education and research involve people and new knowledge. People generate knowledge; knowledge generates technological innovation; and technological innovation makes us competitive in a changing global economy and ensures our economic and technological leadership. This budget is an investment to ensure our economic and technological leadership. It is also an investment in our social well-being.

The opportunities for both investments to pay off are greater than ever. There are critical breakthroughs in such areas of robotics, information sciences, biotechnology, advanced materials, global change, genome research, and biodiversity. Much of this excitement is generated by state-of-the-art instrumentation and approaches to research which bring together individuals, groups, and institutions.

However, our national investments in education and research have been less than that of other countries. As a percent of GNP our spending on research has been relatively flat over a long time, and our investment in civilian R&D is less than 2 percent of GNP (Figures 1&2). Conversely, during this time, other countries have doubled and tripled their investments.

There is also a serious human resource shortfall developing. By the year 2000, the percentage increase in employment of scientists and engineers is projected to far outstrip the percentage increase of total jobs, which suggests very high demand (Figure 3). Yet, there are signs that the science and engineering educational pipeline is drying up:

- o By the year 2000, the number of college age people will be below the number in 1970 (Figure 4).
- o The fraction of science and engineering bachelor degrees going on for the PH.D has been relatively flat.

And to compound matters, according to a recent national assessment of educational progress study, only 6 to 7 percent of high-school seniors are prepared for college-level science courses.

We are also facing a changing composition of our pre-college student population. By the year 2020, minority students will be almost 50 percent of the total, up from about 25 percent in 1982 (Figure 5). Our workforce will be increasingly made up of women and minorities, now largely underrepresented in science and engineering fields. We must meet these challenges head on if we are to increase the number of scientists and engineers we educate and train, and we must improve math and science literacy to cope with an increasingly technological society.

FY 1991 BUDGET REQUEST

Our FY 1991 budget request reflects the critical role research plays in our national economy. It responds to new opportunities within science as well as new challenges brought on by conditions in our culture and the world. It is a strategic program for generating new knowledge and supporting and developing human resources in a changing research environment and global economy.

Our request emphasizes two strategic themes (Figure 6):

- Education and Human Resources-- Developing human resources, broadening participation, and improving science and engineering education at all levels
- Research and Facilities-- Strengthening the research base and improving academic research equipment and facilities.

Research and Facilities is the mainstay of the Foundation, making up the largest fraction of our budget, but Education and Human Resources has become a significantly larger part since the early 1980's (Figure 7).

EDUCATION AND HUMAN RESOURCES

People are vital to the research infrastructure, and they are our first priority. They include not only the future science and engineering workforce pool, but also a scientifically literate public. In focusing on education and human resources, our strategy is to concentrate on critical points in the science and engineering educational pipeline and to broaden participation of under-represented groups. The 1991 request includes over $463 million for education and human resources development, an increase of 30 percent, or $106 million, over FY 1990. Of this total, $335 millon is for education activities and $128 million for other human resource development activities.

Improving the quality of our science and engineering education and developing and broadening our human resources is reflected in the fact that support for education and human resources has grown from $34 million (about 3 percent of the NSF budget) in 1982 to $463 million (approximately 20 percent) in 1991 (Figure 8). More importantly, the number of people we support from high school students and pre-college teachers to post-doctorals and senior scientists has grown from almost 27,000 in FY 1982 to an estimate of 73,500 in FY 1991 (Figure 9).

Pre-college Programs

Our precollege programs are the largest component of our education and human resources effort. In FY 1991, we are requesting $165 million, up from $140 million in FY 1990. We recognize that successful educational programs must be a cooperative effort, involving state and local government, industry, and the public. Our educational strategy at this level is to provide continued support for teacher preparation, instructional material development, and informal science education. This will be complemented by enhanced efforts in our States Initiative to forge strong federal-state partnerships to improve lower, middle, and high school science and mathematics education across the country.

Undergraduate Programs

Undergraduate education is another critical point in the educational pipeline. The quality of this educational level greatly affects a student's interest in pursuing a scientific career. The Foundation has developed a comprehensive range of undergraduate programs that, in FY 1991, will increase by over $44 million or 48 percent to almost $134 million. These efforts involve programs throughout NSF and include support for student research; faculty enhancement; course and curriculum development; and instructional instrumentation and laboratory improvement.

Graduate Programs

Our graduate programs are crucial to increasing the output of the science and engineering pipeline. This is demonstrated in our support for 19,000 graduate students in FY 1991, up from 17,000 in FY 1990. Most of these students are supported on research project grants as research assistants; others are supported on graduate fellowships. New graduate fellowship offers will be increased to 1100 in FY 1991, supporting nearly 2600 fellows during the year. This represents a doubling of graduate fellowships over the FY 1987 level.

Underrepresented Groups

Attracting undergraduates to a career in science and engineering by providing a quality education is not enough, however. Demographics not only show a shrinking pool of college age students to draw from, but also a shrinking pool that will increasingly be made up of women and minorities.

We also try to broaden the participation of underrepresented groups through programs designed to recruit and retain women and minority faculty and students as well as support a broad spectrum of institutions and regions. The Foundation's support for programs to broaden this participation of underrepresented groups has almost tripled since FY 1987 (Figure 10).

The FY 1991 Request provides almost $94 million for special programs for minority institutions and minority, women and disabled students and investigators, an almost 50 percent increase over FY 1990. In addition to existing programs to assist underrepresented groups, such as Facilitation Awards for the Handicapped, Research Improvement in Minority Institutions, and Research Opportunities for Women, the FY 1991 request proposes to initiate an "Alliances for Minority Participation" program to help students complete baccalaureate degrees and make a successful transition to graduate school; and Faculty Awards for Women to recognize exemplary women scientists and engineers. Both of these programs are decade-long programs, not just short term efforts soon to be replaced by others.

RESEARCH AND FACILITIES

The primary focus of NSF support continues to be university-based basic research and capacity-building. Support for university-based research and facilities in FY 1991 is $1.81 billion, an increase of 11 percent ($183 million) over last year. As part of our strategy of a balanced investment, it provides for individuals and groups of investigators, laboratory instrumentation, and access to large centers and facilities, computers, and computer networks.

Our research goals have always been and continue to be the support of people and the generation of new knowledge. And in the present research climate, we seek a balanced portfolio to maximize our investments in academic research. This portfolio must meet existing needs, respond to new challenges, focus on key areas where NSF can make a difference, and leverage national resources.

The individual investigator continues to be the cornerstone of the basic research system in this country. In FY 1991, support for small-scale science, which includes individual investigators and small groups of investigators, is 70 percent of our research and related budget. This form of support is a major source of small-scale research instrumentation as well as the focal point of graduate research training.

But NSF also continues to support research organizations that stimulate the transfer of knowledge and promote cooperation among individual researchers, and that attack disciplinary and complex issues that are beyond the capability of an individual or a group. Eight percent of the FY 1991 request goes to support centers. In this form of support, investigators solve problems on the boundaries of disciplines and provide a forum for knowledge transfer through the training and educating of our future scientists and engineers. Already the first class of Science and Technology Centers (STCs) are showing a positive impact in these areas. A second class of 10-12 STCs, deferred from 1990 due to a constrained Research and Related Activities budget, will be awarded in FY 1991. Our ERC's are approaching a steady state number and no new ones are planned for FY 1991.

The research we support must respond to current issues and opportunities. Accordingly, this budget devotes increasing resources to the global change initiative, genome projects, biodiversity, materials research, arctic research, high performance computing, (which provides state-of-the-art networking for researchers and educational institutions of all sizes), manufacturing research, and software engineering research. As a major part of this effort:

- NSF will roughly double, to $103 million, its support of the President's U. S. Global Change Research Program that seeks to understand, and ultimately, to predict future changes in the earth's environment, such as global warming (Figure 11).

- Support for the genome project, the effort to map and sequence a plant genome, will not only support basic research, but also instrumentation and equipment, providing training necessary to carry out more extensive genome projects.

- A special research thrust on the processing and synthesis of advanced materials, including polymers, superconductors, microstructures, composites, and biomaterials.

Although NSF plays a small role in the total federal R&D effort (about 3 percent), in some education and research areas important to our future social well-being and economic competitiveness, NSF plays a much larger role. For example, we support 37 percent of federal research in high performance computing; 20 percent in land-based global change research; and 10 percent in robotics, semiconductors, and superconductivity. In science and engineering education, we make up 45 percent of the federal effort (Figure 12).

Our support for many of these research initiatives has been a conscious investment for our future competitiveness (Figure 13). We believe they are likely to prove economically important in the next decade or so. Some of the investment has been through large grants to centers and groups of investigators, but much more has been through grants to individual investigators who believe that these fields promise important breakthroughs to new knowledge.

Equipment and Facilities

Quality research needs a viable infrastructure of large-scale equipment and facilities. The request includes continued support for maintaining and upgrading four National Supercomputer Centers, expanding and improving services provided by NSFNET, and building major new equipment.

Our request for major equipment in physics and astronomy reflects the need for international cooperation and joint activities in order to leverage our resources and foster shared use of expensive equipment. Because of escalating equipment costs, there is a greater need for joint participation with other agencies and other nations. Three major equipment initiatives maintain our preeminence in gravitational physics and ground-based astronomy, and, at the same time, leverage considerable international and interagency support. They are:

- Construction of two identical, but widely separated, next-generation gravitational wave detectors in FY 1991 at a total estimated cost of $192 million over four years. Two European groups are planning to build similar detectors, which will, working in concert with the NSF-built facility, permit systematic astrophysical observations in the new field of gravitational wave astronomy.

- Construction of two 8-meter optical-infrared telescopes, one in each hemisphere, and jointly funded by the U. S., the United Kingdom, Canada, and other countries as prospective partners. Design and initial purchase of glass for mirrors will take place in FY 1991.

- Upgrade of the 305-meter reflector at the Arecibo Observatory in Puerto Rico. Costs totaling $22 million will be shared equally by NSF and NASA.

Academic research laboratories and facilities are an integral part of quality research and training. Recent surveys and assessments indicate that they have deteriorated and there is a need to repair, renovate, and modernize them as well as provide new construction. Our request of $20 million for modernizing academic research equipment responds to this need and continues this committee's initiative of last year. Together with the FY 1990 funding, this activity provides almost $40 million for awards made as a result of the first competition.

Safety, Health, and the Environment in the Antarctic

We also continue our major commitment to safety, health, and environmental concerns in the Antarctic. Of the $23.3 million increase in the U.S. Antarctic Program (USAP), $17 million goes toward the safety, environment and health initiative begun in FY 1990. Efforts will concentrate on waste disposal, facilities improvements at South Pole Station, improvements in search and rescue communications, and upgrades in air traffic control and precision landing systems.

Transfer of Funds

In FY 1990, we were provided with two new appropriations, availability of which is restricted until late in the fiscal year. One appropriation, the Academic Research Facilities appropriation, is not available for obligation until September 1, 1990. The other, the U.S. Antarctic Logistics Activities Appropriation, from which NSF is to reimburse the Navy for logistics support to the Antarctic programs, is not available until September 30, 1990.

In FY 1990, we intend to take steps to safeguard naval logistics support activities in the Antarctic without disrupting program activities by transferring the necessary funds from the Research and Related Activities account to the Antarctic program account. Funds will also be transferred to provide for merit review for the Academic Research Facilities program. At the end of the fiscal year, funds which become available in the new appropriations will be transferred back to the Research and Related Activities appropriation, restoring the funds to be used in accordance with the FY 1990 current plan submitted to the congress.

In FY 1991 we have reconfigured the two separate USAP appropriations into one account to ensure continued logistics support of the program.

Program Development and Management

We are requesting a $6.12 million increase (6.3 percent) over FY 1990 for Program Development and Management (PD&M). This represents only 4.3 percent of the total NSF budget, supporting an FTE level that is still below the staffing levels of ten years ago, yet handling more than twice as many proposals today. The majority of the requested increase is needed to fund known pay raises and other cost increases associated with the current levels of staff and services, and provide for 30 additional FTE. We have taken effective measures to control the growth of administrative costs in order to maximize the resources available for scientific research. This request represents the minimum level needed to maintain effective administration of NSF programs, and should be fully funded.

SUMMARY

The National Science Foundation has proposed a $2.386 billion budget for FY 1991, an increase of $300 million over FY 1990. It is the cornerstone of the Administration's $4.66 billion requested increase in Federal R&D because it underpins all other R&D sectors, public and private (Figure 14). It provides the funds to train the people that are needed to carry out the human genome project, build the space station, and devise and implement a space mission to Mars; and it generates the needed knowledge-base across all fields of science and engineering. It is a small, but necessary investment in the nation's future economic growth and security.

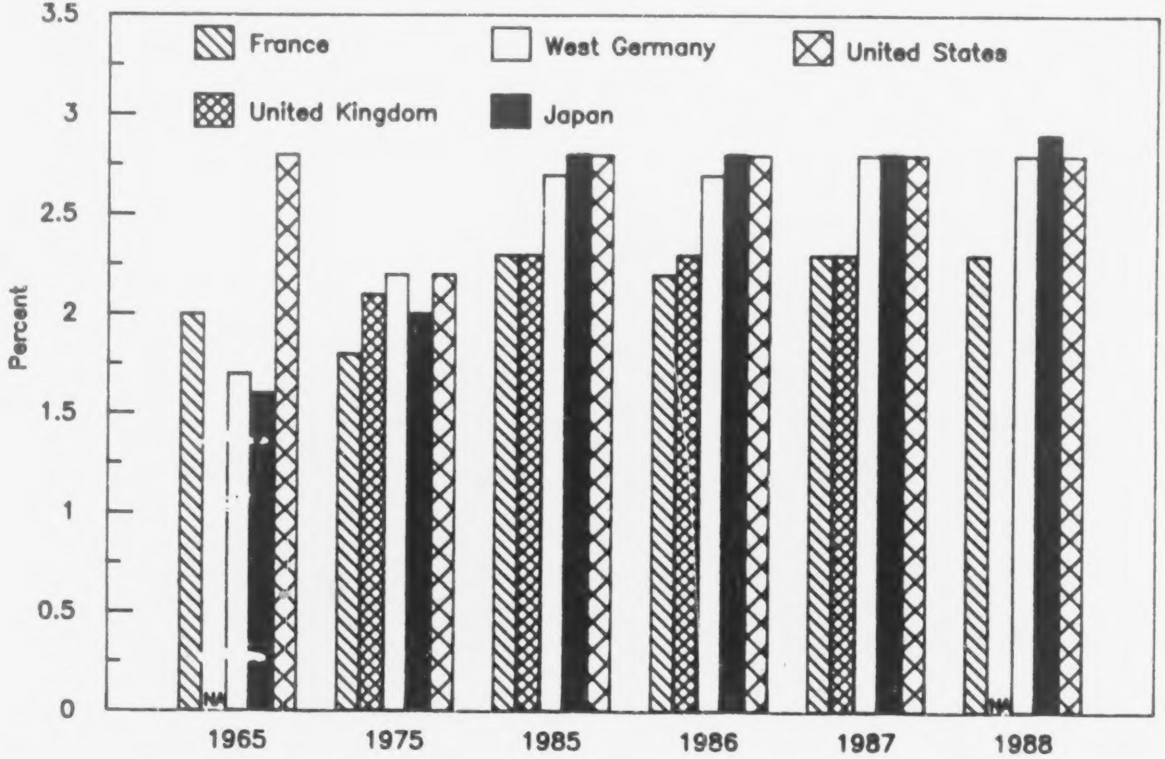
There has been a major disciplinary emphasis between 1945 and about 1975 away from physical sciences and engineering (as represented in DOD and NSF funding of academic research) and towards the life sciences, as represented by NIH's increasing share of federal funding of academic research (Figure 15). Yet, virtually all the industries that have had difficulty with competitiveness - from semiconductors to automobiles - depend more on physical sciences and engineering than on life sciences. The problem would even be worse if DOD support of academic science and engineering were reduced without commensurate increases in physical sciences and engineering research in civilian agencies such as NSF.

The President has already increased the relative emphasis on civilian R&D in the FY 1991 budget - to 39 percent, up from a low of 31 percent in 1986. This is a very constructive move, because our major competitors invest substantially more, as a fraction of GNP, on civilian oriented R&D than we do. This committee has an opportunity, by supporting NSF, to help remedy a competitive disadvantage that has been long in the making.

The budget history of the Foundation, in constant dollars, has been uneven. Growth after 1956 depended on the perception of national need that followed Sputnik. In the same way, growth today rests on the belief that the nation needs a stronger science and technology base. This has been dramatically emphasized by the commitments of both President Reagan and President Bush to double the NSF budget over five years, and most recently in Dr. Bromley's statement to the House Science Committee a few weeks ago.

Despite emphasis on NSF, growth in recent years has not come close to what is needed and recommended by the Administration. Since 1982, the NSF budget has increased about 50 percent in real terms. We have made progress toward the five-year doubling that the Administration proposed, but have fallen short of the mark in the last several years (Figure 16).

We need to do better than that, and I urge you to make this the year in which we begin.



R&D Expenditures as a Percent of GNP
For Selected Countries

Fig. 1

Non-Defense R&D Expenditures
As a Percent of GNP For Selected Countries

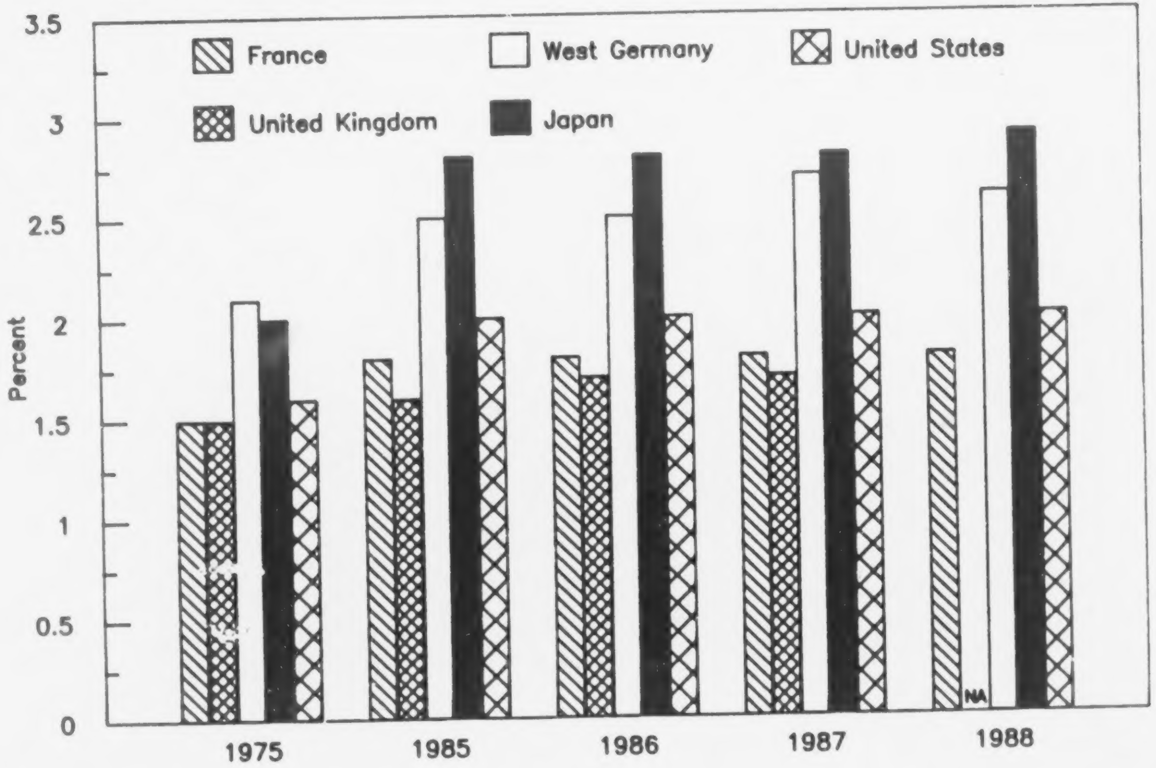


Fig. 2

Projected increase in science, engineering and total jobs in private industry: 1988-2000

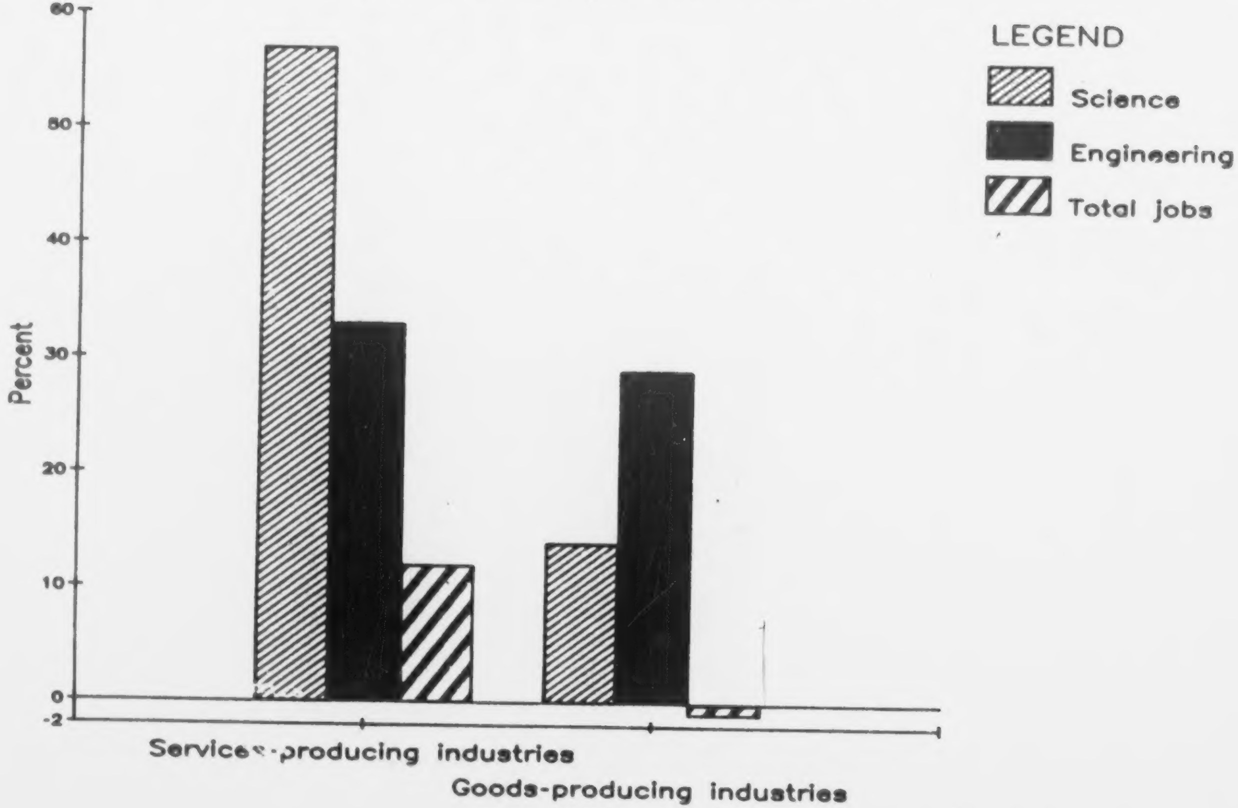


Fig. 3

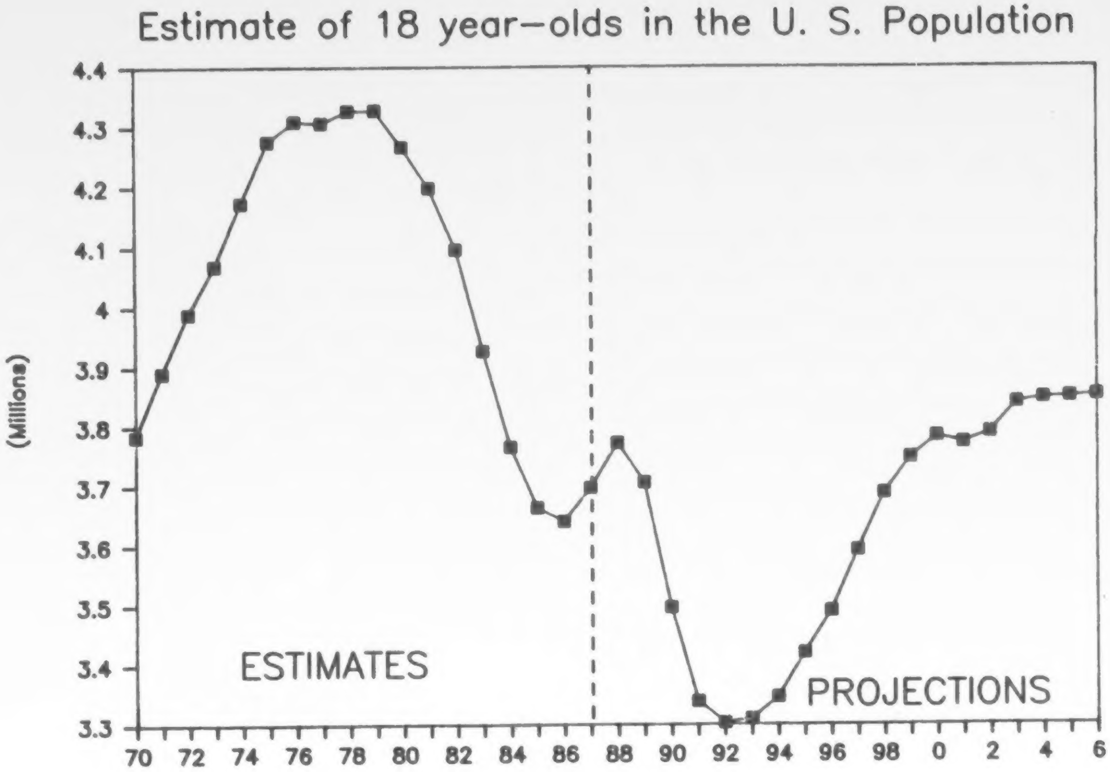

Estimate of 18 year-olds in the U. S. Population
(Millions)
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
ESTIMATES
PROJECTIONS
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98
0
2
4
6

Fig. 4

Distribution of Students
Age 5-17 Years Old

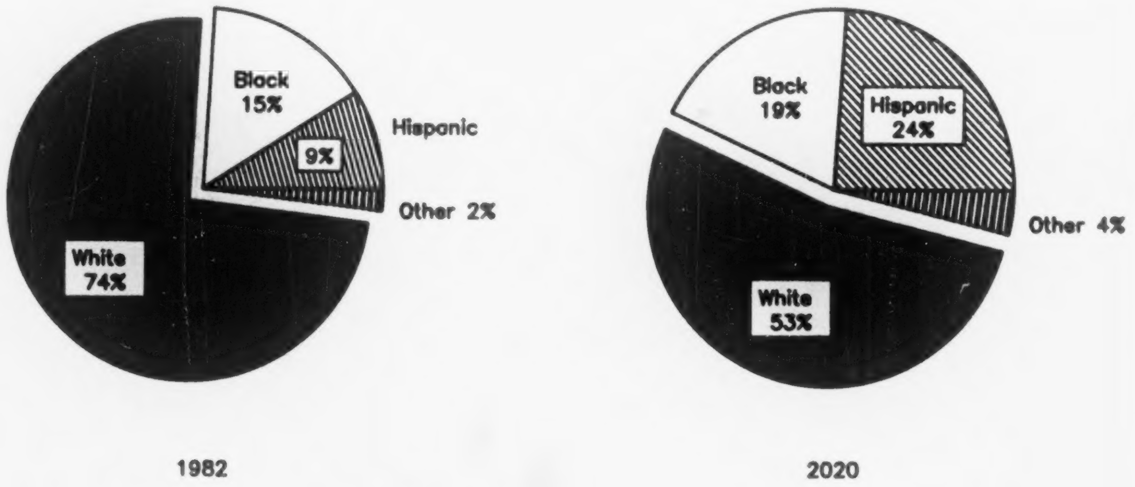


Fig. 5

NATIONAL SCIENCE FOUNDATION
BUDGET THEMES
FY 1990 - FY 1991
(Millions of Dollars)

	FY 90	FY 91	Change	
	Plan	Request	Amount	%
Education & Human Resources	$357	$463	$106	30%
Research & Facilities	1627	1809	182	11%

Fig. 6

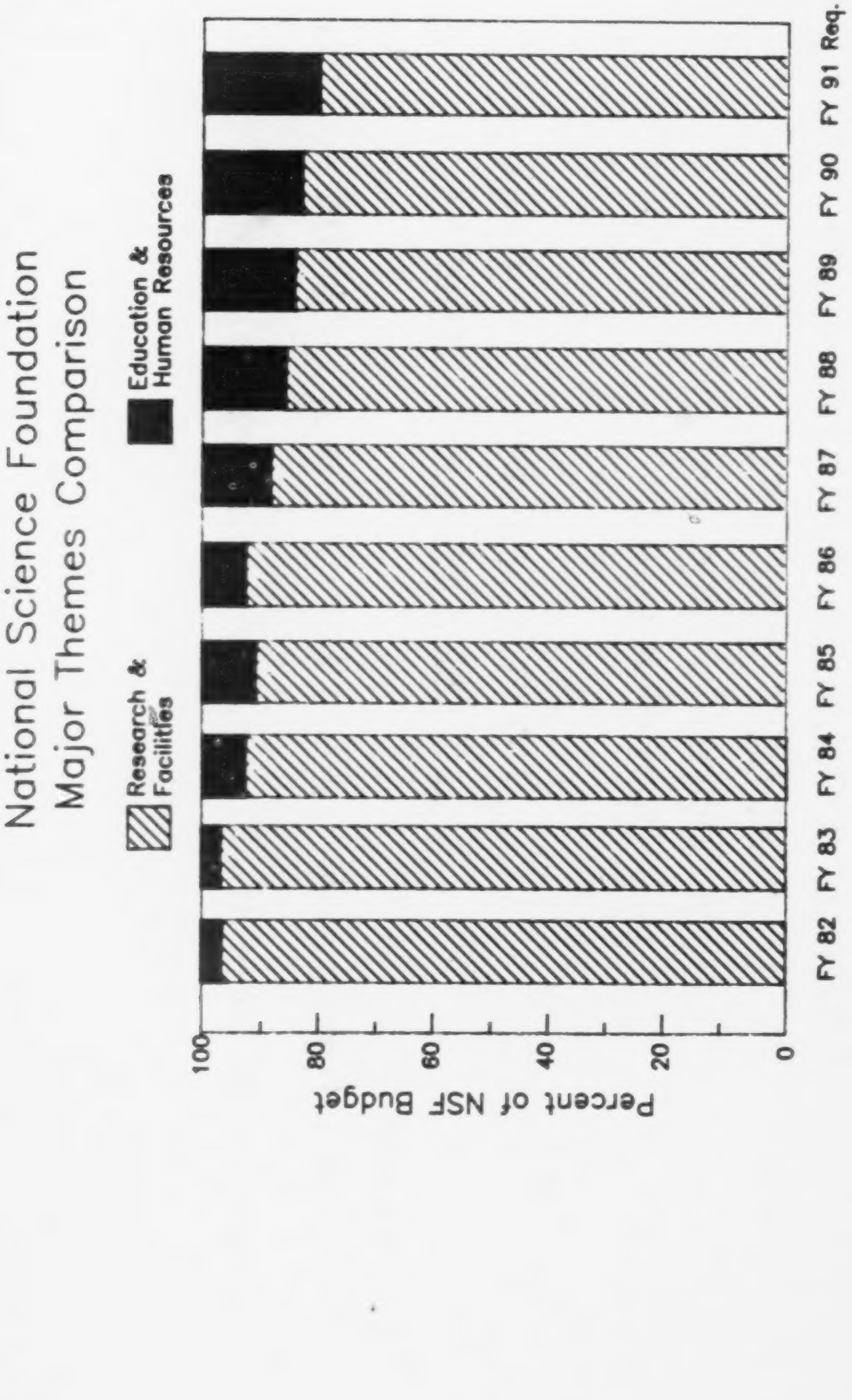

National Science Foundation
Major Themes Comparison
Research & Facilities
Education & Human Resources
Percent of NSF Budget
100
80
60
40
20
0
FY 82
FY 83
FY 84
FY 85
FY 86
FY 87
FY 88
FY 89
FY 90
FY 91 Req.

Fig. 7

National Science Foundation
Education and Human Resources

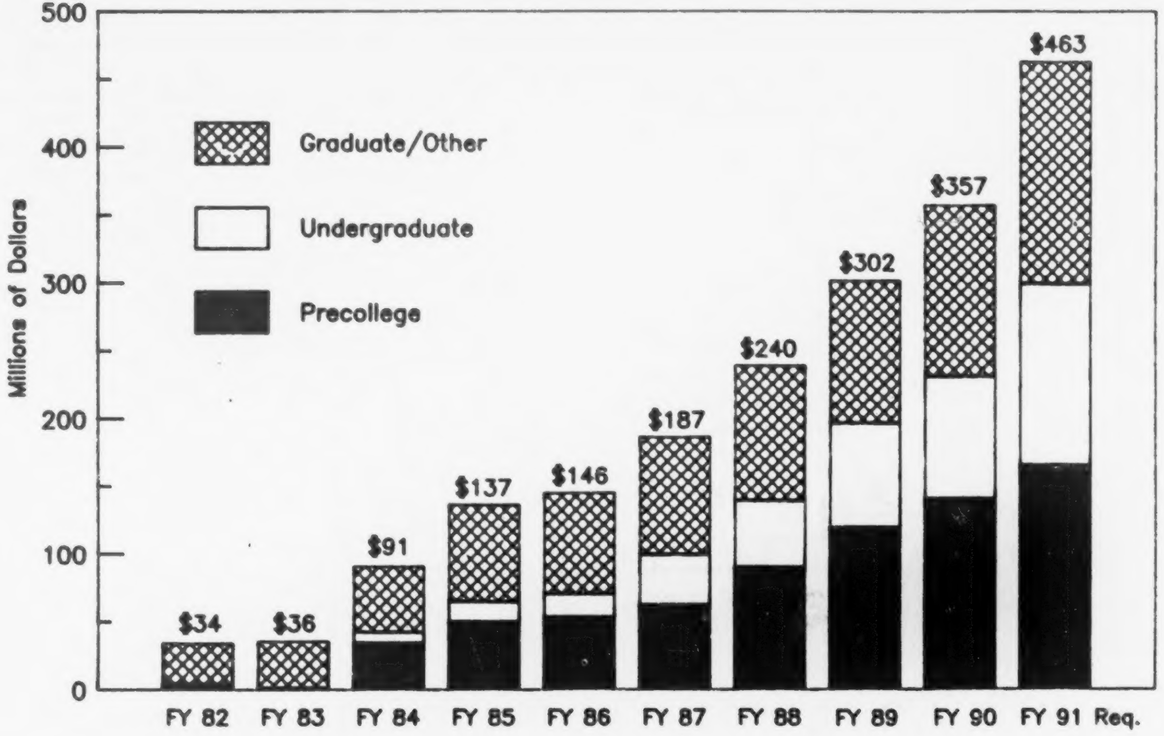


Fig. 8

NATIONAL SCIENCE FOUNDATION
SUPPORT FOR HUMAN RESOURCES

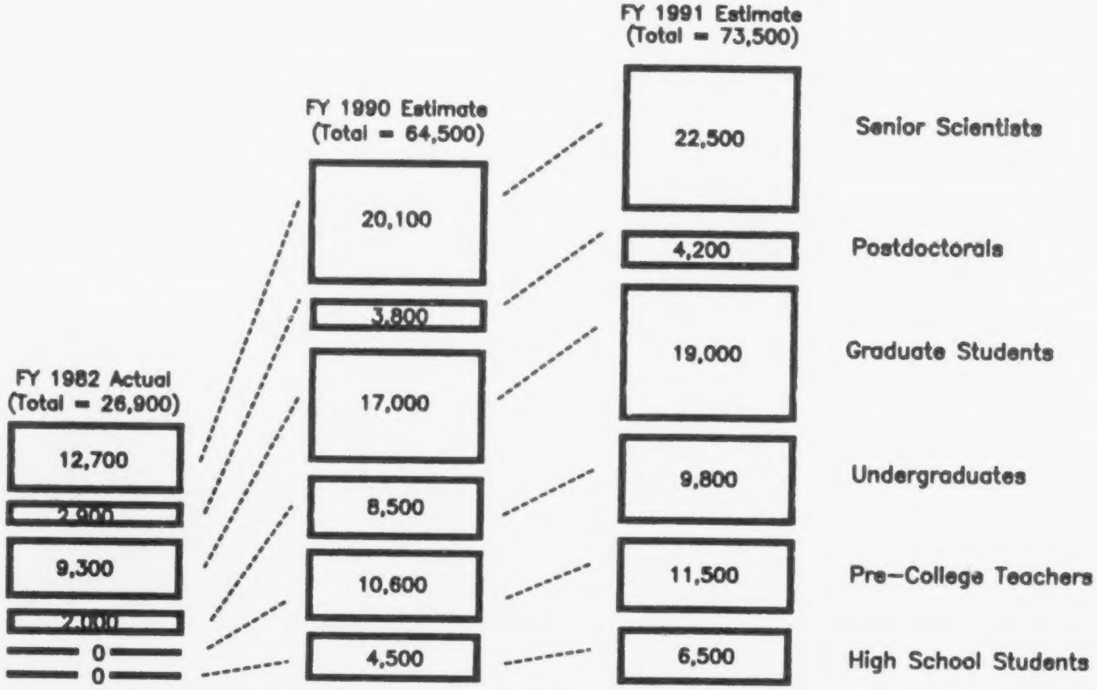
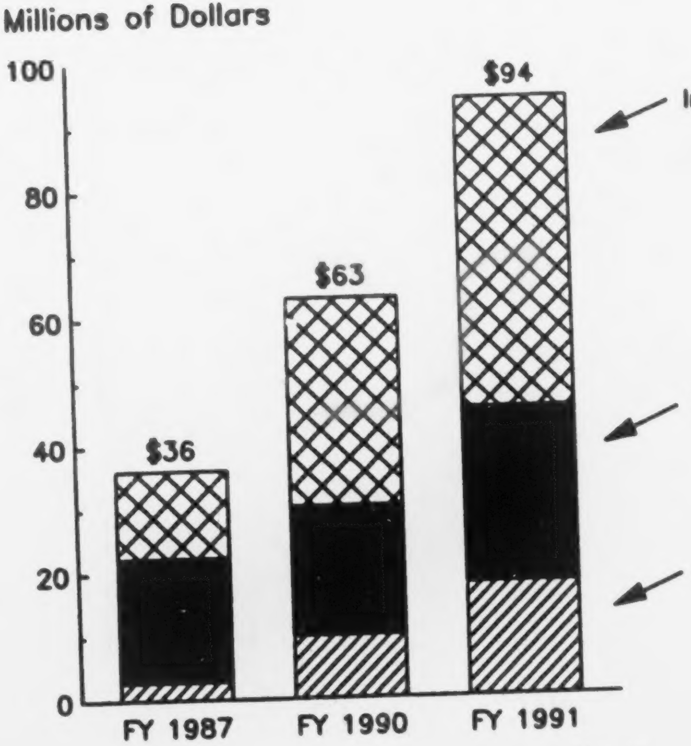


Fig. 9

1-10-90

PROGRAMS TO BROADEN PARTICIPATION



Institutions/Regions -- $49 Million
- EPSCoR
- RIMI
- MRCE
- Career Access Opportunities
- CISE Minority Institutional Infrastructure

Faculty -- $27 Million
- VPW
- ROW
- MRI
- Faculty Awards for Women

Students -- $18 Million
- RCMS
- Minority Graduate Fellowships
- Women in Engineering

Fig. 10

NATIONAL SCIENCE FOUNDATION
GLOBAL CHANGE RESEARCH

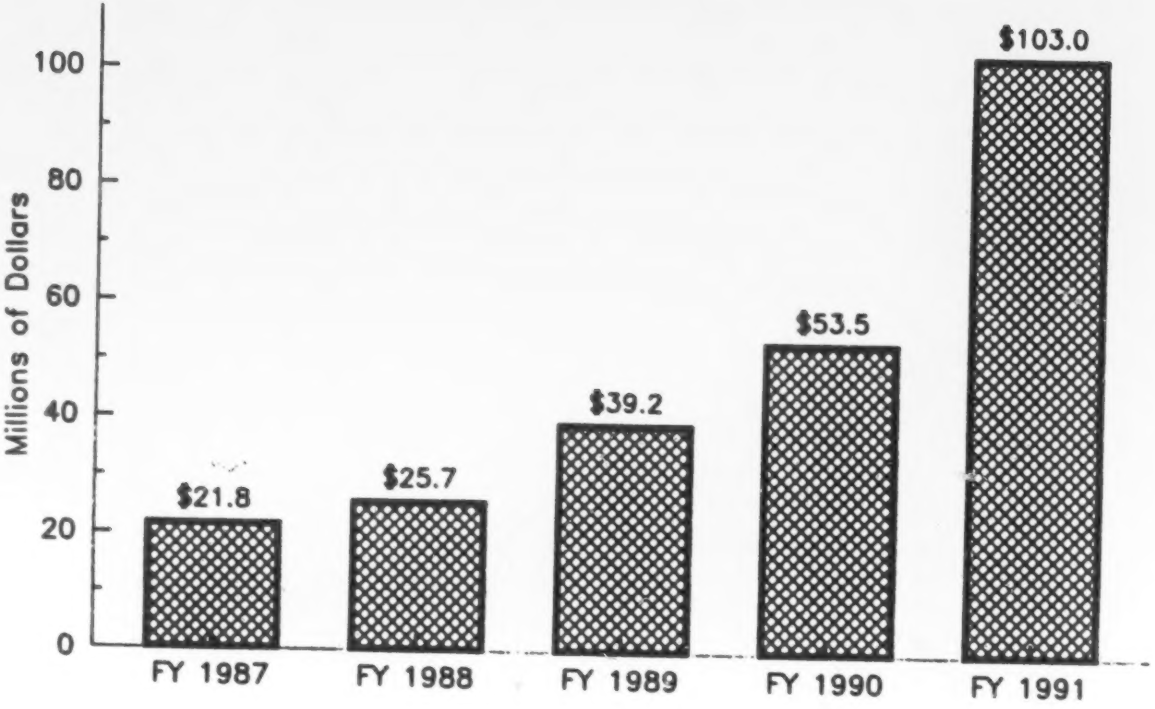


Fig. 11

NSF Share of Federal Support
FY 1991 Request

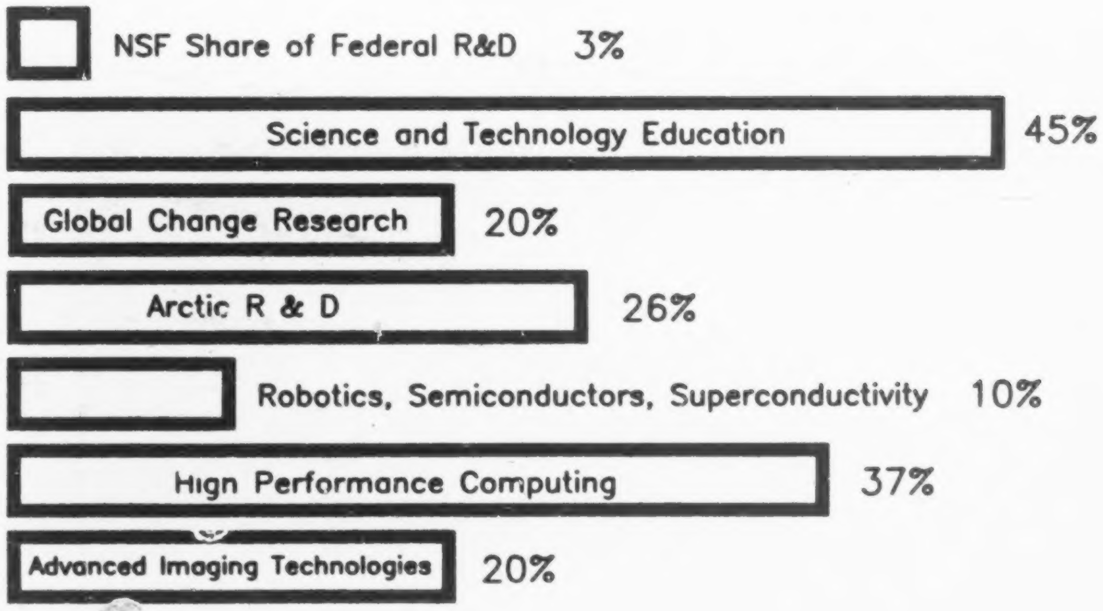


Fig. 12

NATIONAL SCIENCE FOUNDATION
INITIATIVES FOR ECONOMIC COMPETITIVENESS

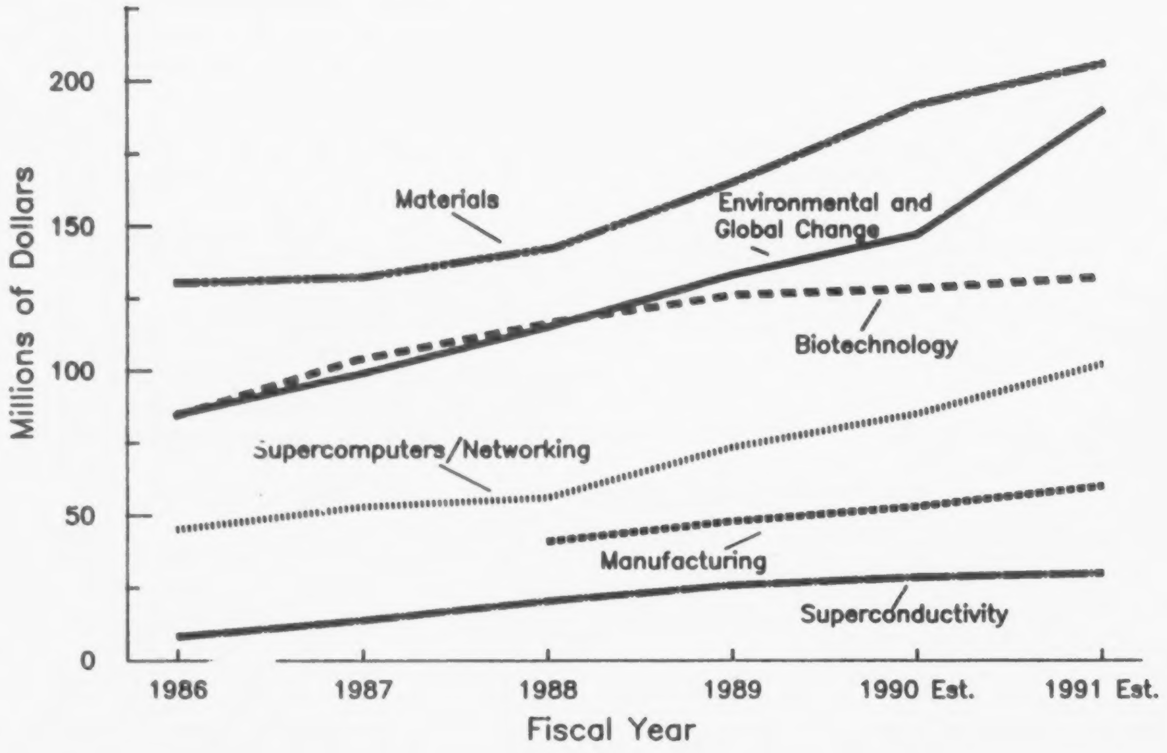


Fig. 13

FY 1991 R&D BUDGET INCREMENT

Total R&D Budget Increment = $4.6 Billion

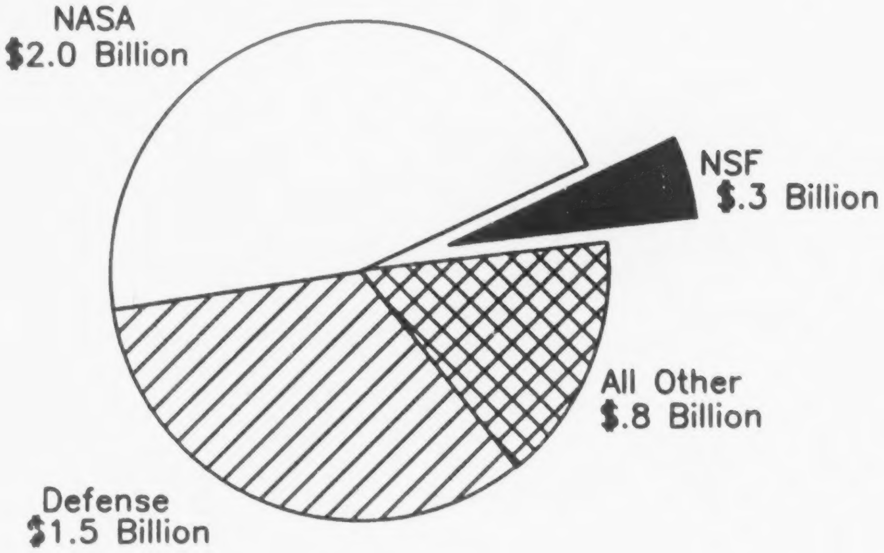
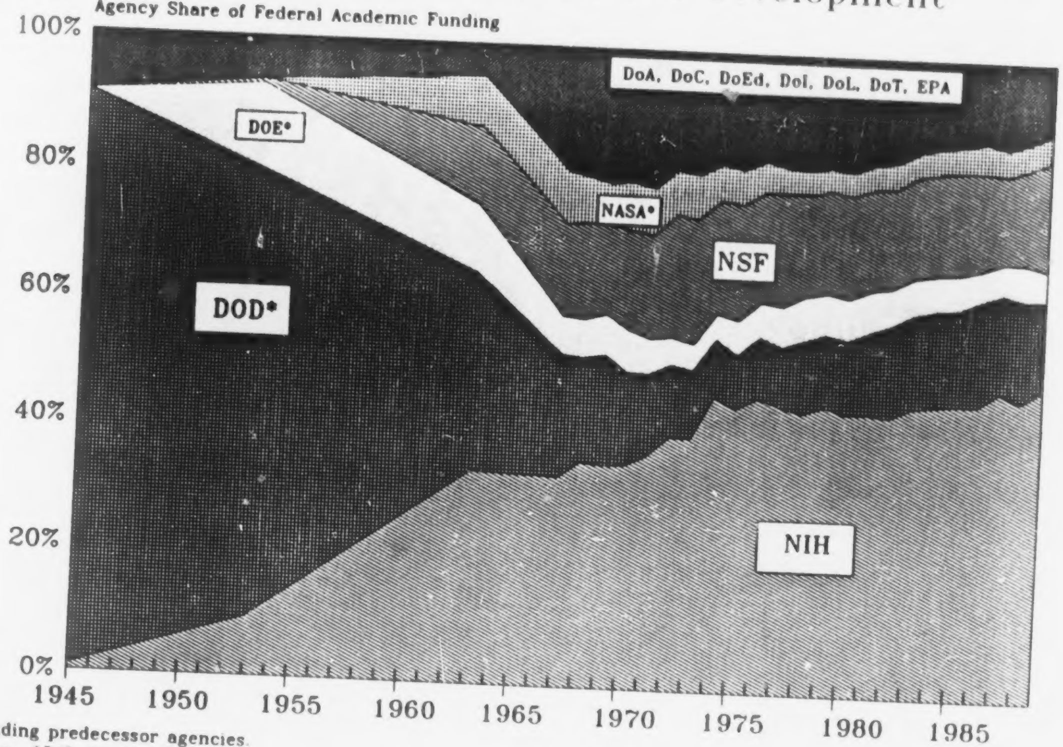


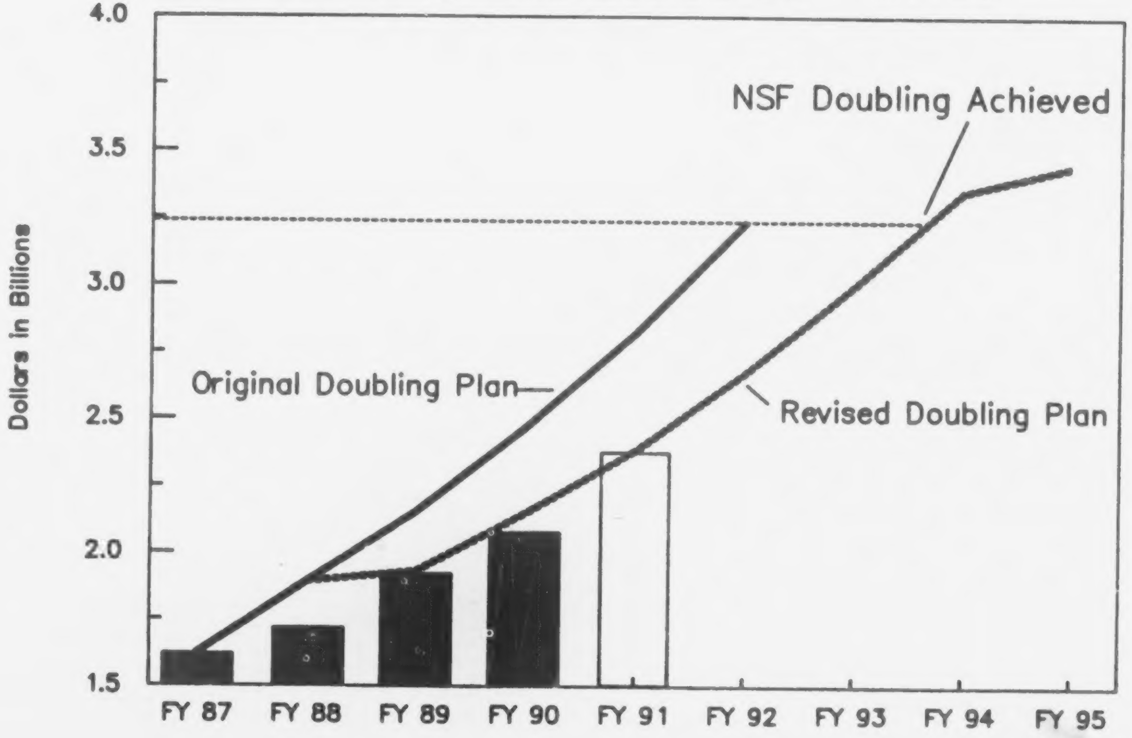
Fig. 14

Postwar Changes in the Influence of Federal Agencies on U.S. Academic Research and Development



* Including predecessor agencies.
Sources: 1945–52, U.S. Congress 1963.
1953–88, NSF Surveys

Fig. 15



National Science Foundation
OMB Doubling Scenario FY 87 – FY 95

Fig. 16

Mr. TRAXLER. Thank you, Mr. Bloch. We appreciate that very fine statement.

I might say that in terms of your FTE, I think you have done remarkably well in the past. You have been very restrained. Whether that was by OMB or out of your own initiative, I can't tell, but you have operated the agency, in my judgment, in a very efficient manner in terms of your staffing and administrative overhead. And we will certainly take a very careful look at your request.

Mr. BLOCH. Some of my colleagues would say too efficient.

Mr. TRAXLER. Mr. Stokes?

WOMEN AND MINORITIES

Mr. STOKES. Thank you, Mr. Chairman.

Mr. Bloch, I am concerned about our whole education picture and where we are going. Dr. Good commented on how we are losing our finest young minds to other fields, fields other than science and engineering.

You have mentioned a situation regarding women and minorities in the field of science and engineering. You have just recently released a report entitled Women and Minorities in Science and Engineering. In that report, you point to a rather deplorable situation, particularly as it relates to women and minorities.

Women are 50 percent of the population. They are approximately 16 percent of the scientists and engineers. Black Americans are 12 percent of the total population. They are about 2.6 percent of the scientists and engineers. Hispanics, 7.2 percent of the work population. They are about 1.8 percent of the scientists and engineering.

We are ten years away from the year 2000. You tell us only six to seven percent of our high school seniors are prepared for college level courses in science. It seems to me that we have got a rather deplorable situation as it relates to preparing our young people for the year 2000 and beyond, and particularly when we look at the year 2020, minorities will be approximately 39 percent of the total work force.

Where are we going? How are we going to get there?

Mr. BLOCH. Well, as you know very well, there is no magic, no single button that you can push to resolve all of these problems. And I think we all are frustrated by that fact and also by the fact that we have not seen tremendous progress, especially with regard to minorities, over the last say 10, 15 years. For a while, it was going up, but it certainly has not turned out to be the case over the long haul.

Similarly, with women engineers and scientists, it went up, and it is leveling off. And it is leveling off at a rather low point, lower than what you would expect.

Many reasons, obviously, for that. What can the Foundation do? We have been focusing on this problem. What we have done is focus everybody on this problem. We have done as much as we possibly could do ourselves in terms of programs. First of all, but also equally important, I think maybe even more important, we have tried to influence the right people in the educational arena, and make them aware of this particular problem. It is not one that is easily accomplished, as I said before.

But many of our programs are aimed at women and minorities that are already in the pipeline.

A number of our programs are aimed at women and minorities that are just entering the pipeline, and I think it is a total of all of these programs, which have continued to look at and refine. We had a major review this year as to their effectiveness, and have put in place new programs to make the total more effective.

We added a program which we are calling Alliances, as I mentioned before to Mr. Lewis, where the Foundation is a catalyst to make sure that states, local governments, school districts and industry participate in the effort. That is aimed primarily at minority students in the precollege areas.

We have added a program—Faculty Awards for Women—for women that are already in a career, but are not getting full professional status in the universities.

MINORITIES AND WOMEN

I had a group of 20 presidents together, because they are the biggest recipients of NSF funds, to focus on exactly this problem.

We are coming out with a joint statement, and hopefully more than a statement, but a joint plan of action of what these 20 universities can do together with NSF or by themselves, to attract more women and minorities. We focused on precollege, undergraduate and graduate education.

What can I say? This is what we are doing. It is as frustrating to us as it is to you, but I think we have to stay the course.

Many times in the past we have started something and stopped it, and I think this is one of our problems. We have to stay the course on many of these programs, and we are not going to see results over night.

Mr. STOKES. Well, I do commend you for the forthright and candid manner in which you have faced up to this problem and made the nation aware of it, and made those particularly who have some responsibility in this area aware of it.

One of the interesting phenomena I found about your report was when you contrasted the progress of women in science and engineering to that of blacks. The progress made by women is about twice that made by blacks. And I am wondering if anyone is looking at that to ascertain if we are doing something in relation to women that we ought to be doing as it relates to blacks and other minorities?

Mr. BLOCH. Well, I don't know that we are looking at that in particular, but you are right in observing that kind of trend.

The point I wanted to make before is we shouldn't relax because we are seeing a leveling off. As a matter of fact, in engineering, we are seeing a dropping of the enrollment.

So what you might see is a great spurt, and then a leveling off at a point, and we certainly don't like that.

So I am not so sure that the problem is different, there is no doubt about it, but I am not so sure that it is a problem for women to solve, either.

Dr. **Good**. Let me just make one comment.

We really have looked at that problem, as well as we could. We don't think we are very good at it yet, to be honest with you.

One of the things, though, Mr. Stokes, that we have really come to the conclusion that the problem with getting women into science and getting minorities into science and particularly blacks is different, and they should not be put in the same pot.

One ought to work on the problem where it is, not just because we have a women and minority program, okay?

Mr. **Stokes**. Certainly.

Dr. **Good**. So, I think that having done that, that it is going to at least have a better chance of beginning to understand the factors.

For example, in the women's case, we have done some really good studies and what it says is everybody would like a silver bullet, which says that if I do this, I will secure this problem. And the one thing that we have learned from these studies is that that is a waste of time, looking for that silver bullet is really a lot of different things from what girls are expected to do, all the way to the point where you get into engineering schools. What they find is a lot of foreign instructors who have different cultures who don't particularly provide a very warm climate for women.

So it is a lot of things, not any single thing. And I think once we made the decision that the issues that make the differences in blacks and the differences in women are not the same, we now ought to look at what those are and target them to try to get it done, and I think we are trying to understand that. It is not a result, but it is at least understanding, and you can't make the results unless we get the understanding.

Mr. **Bloch**. Dr. Good is very right when we talk about women and minorities. The two areas are really separate, and are being looked at by individual programs, not one program that covers both. And I think that puts the emphasis where it should be and also takes cognizance of different facts.

Mr. **Stokes**. I appreciate that very much, and I agree with that approach, too.

Thank you, Mr. Chairman.

Mrs. **Boggs**. May I comment?

We met in Japan with the minister of education who has now gone on to a higher position, and——

Mr. **Bloch**. At least he won an election.

Mrs. **Boggs**. That is right. We found a great deal of dancing around the question about women in science and in science education. We talked a great deal about his wife and what she had been able to do, but I do think that the differences in culture have a great influence upon the kind of education that women get in science from international instructors, shall I say.

Mr. **Bloch**. Right.

Mr. **Stokes**. Mr. Chairman, you have been very generous with your time and I thank you.

Mr. **Traxler**. Very interesting discussion.

Mr. Green?

Mr. **Green**. Thank you.

Let me apologize to the witnesses. My 8:30 flight didn't take off until 9:30.

Mr. TRAXLER. It is like this committee, a little late taking off some mornings.

U.S. ENGINEERING AND SCIENTIFIC WORKFORCE

Mr. GREEN. As you know, one of the matters of concern to us, and to Congress as a whole, is the size of the U.S. engineering and scientific work force. Last April, the National Research Council released a report entitled SAVAK, the Nation's Scientists and Engineers. I am sure you are familiar with it.

They have some of NSF in its report. Let me read one relating to data collection: "Ambiguous subject to misinterpretation by users and very difficult to relate to estimates produced by other data systems."

I guess there was some conflict between your definition of who is a scientist or engineer, and the redefinition used by the Census Bureau and the Bureau of Labor statistics, and one recommendation might be that NSF integrate its data with those of other data collecting agencies.

Could you comment on that and would it take more money to do that?

Mr. BLOCH. Yes, I will comment on that.

That report, by the way, was sponsored by NSF. We asked for it because we wanted to have somebody critically review what we were doing and ask if what we were doing was commensurate with what we should be doing in light of new problems, new techniques and new questions, and like all reports, it found a lot of problems.

One of the problems that you are citing is the incompatibility of definitions between various agencies. By the way, I have had a lot of exposure to that before I came to NSF because I was on one of these forums of this committee that looked at that particular problem. It is not as easily solved as some people might think, because, you know, the census has an entirely different reason for taking surveys than we have. We are trying to, if not make the definitions the same, at least know what the differences are so that we can translate one or the other.

I don't think it would be a very good idea to centralize all of these functions, because they live off different kinds of requirements. But what has to be done more consistently is to make sure that we can bridge from one data base to the other so that we can use each others data by reprocessing it so that it augments the data bases that each agency is responsible for.

We have looked at what it takes to update the SRS activities over the next few years. It takes a certain amount of additional dollars, which we are willing to put in there.

Mr. GREEN. How much?

Mr. BLOCH. Well, right now their budget is about 5 million a year. It has been $5 million a year for some time, and it will probably go up to $7, $8 million.

The total over a period of 10 years?

Ms. TOYE. Right.

Mr. BLOCH. It is about $40 million that we are going to put in there in additional dollars, but it increases and then comes back down, but we need to spend that to make that particular effort.

PUBLIC SCHOOL SYSTEMS

Mr. **Green**. My next question may relate to Mr. Stoke's line of questioning, but you and I were at the National Academy of Science Ceremony honoring the 1989 award winners for mathematics last October. And as I looked over the list of awards, one of the things that struck me was how few honorees were from public school systems. I was puzzled what that meant.

Mr. **Bloch**. Well, I am not so sure I can really throw a lot of light on that, because, as you know, the selection process is not NSF's. It is a competition at the state level, and it is the states that are selecting the mathematics teacher and science teacher that you saw represented there.

Mr. **Green**. I suppose you do have two hypotheses, one that it is a state selection process, and the second, that in some way, big city school systems aren't getting the best science and math teachers.

Mr. **Bloch**. Yes.

Mr. **Green**. Which of those would you think is likely——

Mr. **Bloch**. I really hate to answer your question, but I would say—I would assume it is the latter.

Dr. **Good**. Yes.

Mr. **Bloch**. And not the former.

Mr. **Green**. I guess the question is, what can we do about it.

Mr. **Bloch**. Well, again, we have a program that is focusing on urban school districts to make sure that those school districts have the right support that they need, train the right teachers, have the right teachers. We can't do much in terms of salaries, for instance, which is a very important matter, but we certainly can do something in terms of preparing the teachers in terms of curriculum and making sure the curricula are available to these school districts for implementation.

We are focusing in a small way on that.

CHINESE STUDENTS STUDYING IN THE UNITED STATES

Mr. **Green**. Let me turn to a subject that may relate in a peculiar way, and that is the issue of the status of Chinese students studying here in the United States, many of whom are in the science disciplines. Obviously, it is not enough just to refrain from deporting them. They will continue to need funds if they are going to exist here.

What do we know about whether Beijing has cut off their funds and how they are supporting themselves?

Mr. **Bloch**. I am not so sure that we know more with the kind of information we have, but let me tell you what we did when this situation became apparent last June. We went out to all of our principal investigators and said, look, we are going to make money available to support students that are falling under the President's extension of their one-year stay, and as a consequence, we spent roughly $1.3 million.

Ms. **Toye**. Last year.

Mr. **Bloch**. Last year on supporting Chinese students that fell under that——

Mr. **Green**. How many students?

Ms. **Toye**. One hundred forty-four last year, and I think about 70 more this year, so a total of 200 and some graduate students.

Mr. **Bloch**. I should tell you we were the only agency that did this, by the way. What we expect is that this year, in 1991 certainly, and after we finish funding what we are funding in 1990, which is about a half a million dollars more, that these students are going to get picked up in the normal way through our normal process.

We just have been at a point in time when this became very urgent, and where there was no flexibility with the individual investigators own area to do something about it.

Mr. **Green**. As you may know, I represent a substantial Chinese American population, because I represent Chinatown in Manhattan, and there have been some suggestions from that community that perhaps the group of Chinese students who are stranded here might be available on some sort of basis as some extra people who might be swung into the local school systems.

Do you see any possibility of that?

Mr. **Bloch**. Well, I am sure there could be chances like that, but let's not forget that these people came over here for a purpose. They came over here to pursue a Ph.D. or to do research in a particular area, and I think they are very bright and they are contributing, obviously, in a significant way, and I doubt very much that many of them will have any problems, you know, staying in that kind of an activity.

CENTERS VS. INDIVIDUAL INVESTIGATOR

Mr. **Green**. If I could turn to another subject.

Obviously, you emphasize engineering in recent years because of concerns with the country's international competitiveness, and a recent report from the National Academy of Engineering has favorably reviewed the engineering research center program. I am sure you are pleased by that report.

The statement has produced some backlash in other parts of the science and technology community. I am, for example, referring to a paper by Dr. P.W. Anderson in Princeton entitled "Has the Science Funding System Broken Down," basically suggesting funding for small science and individual investigators has broken down leaving very dispirited young scientist. While his paper uses condensed physics as the example, it is his intention that the problem is much beyond that field.

Would you care to comment on that?

Mr. **Bloch**. I would be glad to comment, and I am sure Dr. Good would also comment.

There is no doubt about it, that as soon as you introduce a new concept, and by the way, the centers concept was not that new, because the National Science Foundation and other agencies have had centers since time immemorial, if not longer, but as soon as you put a focus on something in a very constrained financial environment, you are going to get those backlashes. Everybody is saying, well, you took the money away from me, me being the individual investigator, as one particular example. By the way, they also focus on big science and the definition also includes facilities. I would just want to say that we need both; that we need centers and groups, as well as individual investigators, and honest people can have honest differences where the balance lies. And I think that is the basis of the problem.

We have centers and have been living with a budget item for centers that is less than 10 percent. And we have made that promise to this committee, and we have kept that promise.

Support for individual investigators is close to 65 to 70 percent of our research dollars.

But I think what we are seeing is what the community sees; namely, a tightening of the budgetary problem, and they are seeing it in a number of ways.

While our number of grants have been increasing significantly, I will say significantly increasing over the last few years, the size of our grants has not; okay?

It's the cost of doing the research that has been increasing in a significant way. We have more people entering the system, and as a consequence, our yield has been dropping to about 30 percent, from a high of 38 percent from 10 years ago. And that is all being felt.

NSF AND NIH AWARD SIZES

Mr. Green. Your comments led into another complaint I have had from the Rockefeller University in New York where they assert that NSF grants average about one-half of those from NIH and also run for shorter time frames.

Mr. Bloch. Well, that is correct.

Mr. Green. What leads to that disparity?

Mr. Bloch. Well, our budget is about a third of NIH.

Dr. Good. I would make a comment on that. I really do think you have to be—the Board looks very carefully at this whole issue of centers versus principal investigators because there is a major discussion in the country about that.

The issue really though is that the National Science Foundation funds the entire infrastructure in basic engineering, the physical sciences, you know. This includes today the kind of thing that Phil Anderson is interested in, but it includes materials.

And when you really look at the budget that the NSF gets to provide that kind of a foundation, it's truly inadequate in today's world because the economy and the new manufacturing issues and the new product issues that we are trying to be competitive with are all based on that base, on new materials, new manufacturing technology, new ways of doing analytical work.

And the huge portion of the funding for all of that activity comes out of the NSF, and we simply no longer have a big enough budget to adequately address that.

It just isn't there, and the infrastructure is beginning to feel that very much. And agencies like DOD which funded some of it in the past, the amount that is coming to fill those gaps is just nowhere to be found.

So I think you are going to hear more of those kinds of complaints because we are just no longer with the budget we have able to respond.

Mr. BLOCH. You weren't here, Mr. Green before, but Mr. Lewis thought we were spending too much money on research before.

He wanted us to spend more on education, and I said well, I agree with that, okay. I agree with both you and him.

Dr. GOOD. Absolutely.

Mr. BLOCH. But to do it right, we have some requirements. New investigators is another thing. The Board is looking at how many investigators do we bring into the system.

Phil Anderson represents one of the customs, so there is a conflict there. We need to look at our young investigators to make sure that we have some wherewithal in 30 years when the Phil Andersons of the world are a thing of the past, and that is another requirement.

PRECOLLEGE EDUCATION

Mr. GREEN. One final point.

We have encouraged you to get into elementary and secondary education, and you have responded. Also we have seen the Department of Education has made a major contribution. How do you two coordinate your efforts?

Mr. BLOCH. Well, we have over the last few months in particular, and in fact, going back three and four years ago, we have had many discussions with the Department of Education.

The problem of cooperating in a programmatic sense is essentially that we have a lot of flexibility; what programs we can start, what programs we can undertake and consider.

The Department of Education doesn't have that flexibility. It's being controlled very closely by Congress and what it can do with the dollars that it has available. It is more difficult for them.

We have been working closely together on informal education problems. We are jointly funding 3-2-1 contact, and Square One-TV. So in that area, we have worked very closely together.

We are using the Department as a distribution channel for some of the materials that have been developed on the NSF's budgets and that, I think, is going on reasonably well.

It's a big job, and we don't have the wherewithal to do that, whereas the Department of Education does.

We are meeting very often with the policy counsel and with the Secretary of Education. I think we have a very cordial relationship. We are appearing together tomorrow in front of the House Science and Technology Committee to address exactly the question that you are asking.

Dr. Luther Williams is the coordinator from our end, and an equivalent person from there is his counterpart. So we are trying to get closer and closer together.

But I think we have a problem that our mission is a little bit different and what we can do is a little bit different than what the Department can do.

Mr. GREEN. Thank you, Mr. Chairman.

Mr. TRAXLER. Thank you.

Mrs. Boggs.

EDUCATION

Mrs. BOGGS. Thank you, Mr. Chairman.

We have done, of course, a great deal of questioning and exchanging of views on education because it's just so very important. But, I do think that some mention should be made, not only of your request for substantial increases in education and human resource programs, but for global change, basic research, and the Antarctic, safety, environment and health initiates.

I think we should look at major research equipment and facilities closely, especially because of the substantial international involvement in several of our projects, including the Laser Interferometer Gravitational Wave Observatory. In fact, two European groups plan to build detectors similar to that. Dr. Good has also talked about the wonderful international cooperation of the U.S., the U.K. and Canada, and the planned funding and construction of two eight meter optical infrared telescopes, where we are paying half and they are paying half. So that's very good.

Also, I was interested in the cost sharing between the National Science Foundation and NASA in upgrading our Arecibo Observatory in Puerto Rico. I think that you are making great strides in this cooperative effort.

I simply wanted to mention those and to commend you on all of these initiatives.

Mr. BLOCH. Very good.

Thank you, Mrs. Boggs.

If I can may comment on it. It won't be very easy to trade those projects off, and let me explain why.

There is a certain amount of mistrust, if we are staying our course once we enter into such an agreement, and that is primarily due to the fact that the Foundation doesn't have a pile of money that has been allocated to the construction of either the gravity wave detector or the eight meter telescopes.

But we are going on a year-by-year funding, and what you see in the 1991 request is the initial down payment, so to speak, for these two important programs.

They are of long duration, five, six years, before they are completely built. And in the past, we have stretched out programs, we have delayed programs, we have discontinued programs of this sort.

There is a certain amount, I must tell you, of mistrust by other countries if we really mean what we are saying.

I must also tell you that I have a certain mistrust of some of the other countries, also; okay? So that is the environment in which we are trying to operate.

I have been—I don't make it a secret, I have been asking OMB to fund both of these programs in their entirety. Obviously I didn't succeed. That would have put a stake in the ground, and that would have made our proposal to these other countries a lot more—they would have received it with a lot more interest than if they only see one year funding.

But nevertheless, whatever the case might be, all I am saying is once we start on that particular road (and by the way, it's very important that we come to an agreement before we start these programs, not after they have already started) that we then hold the course.

And I just want to mention that here, because this committee plays a very important role in making us more acceptable to our partners overseas.

Mr. **Traxler**. I would like to interrupt for a moment.

Mrs. **Boggs**. Certainly.

FOREIGN PARTICIPATION

Mr. **Traxler**. Earlier there were some comments on the area that you have been referring to. We talked about foreign participation in projects, and I stressed that I had some concern about how these negotiations come off and how well we do as a Nation at the bargaining table defending legitimate positions.

I was thinking about one project that has been delayed through no fault of our government, the Hubble Telescope. The original deal was that our foreign partners would have a 15 percent time usage.

The telescope's price has gone up because of storage and the new functions they added to it during the storage period, and low and behold those costs were all borne by our government, our taxpayers.

Mr. **Green**. That is right.

Mr. **Traxler**. Their time usage went up from 15 to 20 percent in the meantime. Thank heavens we are going to get it launched.

Dr. **Good**. That is right. Because it will continue if we don't get it up.

Mr. **Traxler**. I think their demanding more time is sort of payment on the interest.

Dr. **Good**. Yes. For a payment on the deal, as I understand it.

Mr. **Traxler**. Incredible, how we could have so-called negotiators sitting at the table giving away the store in that fashion is totally beyond my comprehension, and I might add, many Members of Congress, and certainly the American public, if they knew; unfortunately they don't.

Dr. **Good**. Right.

Mrs. **Boggs**. We have just gotten somebody from the State Department to come over here ourselves, so maybe we will settle all that.

Mr. **Traxler**. I am worried about what will happen to NSF.

Dr. **Good**. The culture over there is pretty heavy. I think it will be all right.

WOMEN AND MINORITIES IN EPSCOR STATES

Mrs. **Boggs**. Of course, it's always been very close to my heart, and certainly the discussion about educational programs for women and minorities has been very heartening to me this morning.

Unless we follow Dr. Good's advice and create some new wealth and thereby some new products, new technologies, and new industries, we are not going to really attract the young people into science and math as we should.

I had a very chilling suggestion from Dr. Eamon Kelly, President of Tulane University. He said that, if young, white men continue their current career trend into law and business, 95 percent of all women and minorities will have to go into science and engineering between now and the year 2000.

This is obviously a frightening prospect. An issue closely related to the under-representation of minorities and women which we have discussed several times before is the distribution of research and development funds.

Many poor states have high minority populations. They also tend to receive fewer Federal R&D dollars. It would therefore seem that by ensuring that more Federal R&D funds go to these states and their institutions, you would accomplish the dual task of improving the quality of research performed within the state and reaching more minority students there.

I know, of course, that you strongly support the EPSCOR program. However, given the fact that so many minority students reside in EPSCOR states and that EPSCOR states comprise approximately one-third of the Nation's states, is any effort made to target a percentage of the graduate fellowship programs or general science education improvement funds to those EPSCOR states?

Mr. Bloch. No. The answer to that last question is no. We have not targeted any of the graduate fellowships to EPSCOR states.

Honestly, they are eligible, just like everybody else. As you know, it's a graduate fellowship program which is primarily driven by the individual who applies for it, and the grant is not tied to a university. It's tied again to the individual.

He or she can go anywhere with that graduate fellowship and start their career or their studies wherever they want to.

So it would be very difficult, to tie it to particular states. We want to focus on the individual and not on a geographic regions, or even an institution. We leave it completely open, what institution the individual wants to take that graduate fellowship to start their study.

So I don't think that would work. But your point on EPSCOR, I think, is a very good one. We started that program to bring the states up to a more acceptable and competitive level, compared to the other states that are in the forefront of research and education.

We are focusing the EPSCOR program, not only on research, but on education also. And hopefully, by changing the environment in these states, or especially in these universities, they will become more competitive or their students will become more competitive in getting graduate fellowships.

EPSCOR

Dr. Good. Could I just make one comment. I happened to go to the EPSCOR conference in Puerto Rico, and I would like to comment on that just for a couple of minutes because it is an instance of how a little money can go a long way.

The Puerto Ricans used their EPSCOR to do some creative things. I met the young man who is the President of the University of Puerto Rico, one of the most dynamic people I have met in a very long time.

He has upgraded the university, utilizing some of those funds and whatever else he's been able to scrounge, but he is now to the point where he's enticing Puerto Rican students from New York back to the University of Puerto Rico to get an education. Probably he will end up with more educated Hispanics than we have in the whole system, would be my guess.

But there are some really nice success stories in that kind of a situation where he has done some really excellent things in terms of turning on some students who really, in the past, have not even been in the system at all.

Mrs. BOGGS. That is a wonderful report.

Four hundred twenty thousand dollars has been requested for a new college and university innovation research program to facilitate development of high technology products derived from academic research results.

What effort will be made to ensure that some of these projects are located in EPSCOR states?

Mr. BLOCH. Again, that is really the analog, so to speak, to the SBIR program, which has been in existence for a long time, which the Foundation pioneered and which is now, by the way, supported in all agencies.

It's a program where an individual investigator or researcher in a university comes forward with a proposal that has industrial success, essentially, or hopeful success, and comes to the Foundation to ask for a grant that will allow them to develop these ideas in more concrete form, but not so far that it will be essentially a product in Phase 1. So it's completely different to the SBIR program.

Again, that depends on the individual researcher, no matter where he or she is, to come to the Foundation with a request.

Again, we are not targeting the institution. We are targeting the individual researcher, and I would hope that a number of researchers wherever they are, EPSCOR states or not EPSCOR states, will come forward and avail themselves of that program.

I should tell you, it's an experiment. We are starting it at a slow a rate, just to see how it will develop, and also what the pull of the program will be.

We are even in the EPSCOR states. In fact, we are going to make some new announcement in the next several days.

Mrs. BOGGS. I really do believe, of course, that NSF serves as a focal point for education initiatives within the states where EPSCOR is located.

As Dr. Good has insisted and as various reports and studies have repeatedly pointed out, there is a close linkage between research activities and economic development, including our competitive position in the world.

However, I am also interested in your views about other effects that strong, active research programs, particularly those at colleges and universities, have on the communities and states in which they are located.

Do you think, for example, that such programs increase public awareness of the importance of science and technology, and what effect do they have on precollege education?

RESEARCH PROGRAMS

Mr. BLOCH. Well, I am sure Dr. Good wants to comment on that question, but let me start it off.

I think that these programs have a big effect on the local communities and the states themselves. In many cases budget dollars that go to individuals or centers or groups, are augmented by local industry, and not only local independent industry but national and sometimes international industry, and are being augmented by state dollars too.

The center program that was mentioned before, Engineering Research Centers, and some centers that are not funded by the National Science Foundation were funded by local contributions from states, industry and universities themselves.

Sometimes you don't have to go so far and put a grant out there. Just the fact that one particular proposal did not succeed in attracting the grant, but was highly rated, has a bearing on what goes on later in that university and with that particular program.

There are many of these examples, and I am sure Dr. Good wants to comment.

Dr. GOOD. The issue of basic research and what its impact is on the country, I think, is a legitimate question when times are hard and money is hard to get.

But I have made the comment to the Board several times, and that is that if you remember, there has been no civilized nation anywhere ever, since recorded history, that didn't have a program in astronomy.

You wonder, astronomy? What does this have to do with what goes on in the world? But there are certain things that the public really wants to know.

What is it that makes the world go around? Where is the end of the universe, and that sort of thing. So if you look at civilizations, those are the kinds of issues and the kinds of intellectual activity that distinguishes between a country which has low hope and low levels of education and a country that has something to offer its citizens other than just bread, and bread is not enough by itself. It really isn't.

So those kinds of programs, I think, are simply parr of the fabric that makes up society as a whole. Then some others get very close to home.

BASIC RESEARCH

For example, take one I know best. If you take materials today, the Japanese have targeted advanced materials as the vehicle to move to number one, keep the position they have in electronics, and to move into the other high technology areas like aerospace that they don't presently have.

We in this country do much of that research in advanced materials in universities. Here is where it gets done. That is the way we have chosen to do it.

Now, whether that is right, wrong or indifferent, it's a little too late to start over in the middle, because that is how the basic research gets done.

In Japan, they do it in the industry, primarily, not in the university. So there you have got direct connections. If we don't do it well and do it best and do it first, we are going to be in deep trouble as to being able to compete and keep up.

And the other issue is that if you have a quality university in the area, as I think everyone of us knows, there is no question about the difference in the quality of the state, the quality of life, all kinds of things that go with it. In fact, people have made some very good studies of that—and in the United States the social benefit from basic research is much higher than the direct economic benefit.

So we have done very well with the social benefit. We haven't done as well as we might have done, perhaps, on utilizing it for the economic benefit, and in today's world we have simply got to do both because the rest of the world surely understand the economic piece.

And we have got to get it coupled better, use it better, and get it out there first. I think the case can be made across the board that it is the essence of what makes a difference.

Mr. Bloch. By the way, on a very general level, if you look at the total R&D budget that goes to universities and colleges over the last 20, 30 years, the Federal support for that budget has been dropping in percentage terms.

As the slack has been taken up by state funding and industry funding, plus a little bit from the universities themselves, it's interesting that today more and more state dollars find their way into R&D.

The states wouldn't do that if they didn't expect, couldn't expect a return, and the return is their industries' competitiveness, either on a national or international level. But there is a profound shift that has been going on over the last 10, 15 years.

EASTERN EUROPEAN DEVELOPMENT

Mrs. Boggs. In the international arena, what effects are the Eastern European developments going to have on our programs?

Dr. Good. Erich, you want to make a comment?

I will start. Mrs. Boggs, I think the Eastern European situation, the opening up of that, how that is going to impact is yet really to be understood. But it's going to have, I suspect, major, major impacts.

I would guess that we may very well get lots of student applications from the East that we have not gotten in the past. I think you are going to see opportunity for people to move, either to European universities or to come to the United States for their education.

I think there are going to be some major impacts. The one thing I think that has to be understood is that infrastructure in many of those countries is in such bad shape that one is not going to be able to get much in return on an early basis.

People talk about new markets and that sort of thing in Eastern Europe. Yes, they will be there, but they will not be there tomorrow because they are going to have to build the infrastructure before those kinds of things happen.

I suspect that the universities will end up with lots of students from Eastern Europe that we have not seen in the past.

I think they will come, and many of them hopefully will not only come but go home and help do that infrastructure, which is what it is going to require.

So I think it's going to have a major impact.

IIASA

Mr. GREEN. I notice that the White House did release the IIASA funds, and I gather that you played a major role in that negotiation. Do you see that as perhaps a vehicle for participation in Eastern Europe?

Mr. BLOCH. Let me talk about that for a minute.

I knew it would come up sooner or later, and then I would want to come back to Mrs. Boggs' question on East European cooperation in particular.

As you know, over the last three years we have been funding projects within "IIASA" on a project-by-project basis. It's different than the way it had been funded in the early 1980s. They funded the institution, essentially.

The projects that we have been funding are very good. We have no qualms about the contribution that we are making to IIASA that it wouldn't make a difference. It will.

We have just, and the science advisor has written a letter, to that particular effect, we are just trying to negotiate with IIASA a different kind of a permanent relationship, one based again on project-by-project review rather than on funding the organization.

We also hope that this will open up participation of other agencies in that process. It should look to NSF as being one of the funding agencies once the EPA has had a continuing interest in the work that is going on in IIASA with the geosciences program and the whole global environment program. There will be other agencies that will find it useful to work with IIASA. We are trying to renegotiate that during 1990.

We also have suggested to IIASA the possibility that they can not only ask for one year funding of a project but multi-year project funding.

We leave it up to them to determine what multi-year means. Up to now, we have done it strictly on a year-by-year basis. I think this will open up things, also.

We hope that we get back with IIASA on a broader scale than just NSF or just one project, but I think we should keep to our view that we would want to support IIASA not only on an institutional basis. I think it puts us on a much better level essentially.

EASTERN EUROPE

To come back to Mrs. Boggs' question on Eastern Europe, we just signed a few months ago, an agreement with the USSR that will put in place some activities in the basic research areas like mathematics, on an individual-by-individual basis—one individual from here, one individual from the USSR—can come forward to us and to the USSR Academy of Sciences for co-funding of a particular project or a particular program or a particular piece of research.

This is a new way of operating with the Soviets. Before the cutoff, we operated on a tops-down basis. Both countries selected the areas, and in many cases even selected the individuals; whereas now we are trying to put it on a bottoms-up basis.

Eight or nine basic research areas have been identified; earthquake engineering happens to be one. Some of the biological areas have been identified, many of the geoscience areas have been identified for a mutual kind of interaction.

We have to see how this works. There is a great interest in the Soviets but we should realize that they are changing their whole way of operating as a basic research effort.

Mrs. Boggs. In some of our U.S. arrangements with the Soviets, we have had components of their corroboration performed by Czechoslovakia or another country. What happens in situations like that?

Mr. Bloch. I don't know what happens in situations like that. But you should also know that we have had relationships with Poland, Hungary, and Czechoslovakia over the last few years.

I think we are going to intensify those. But these countries are not foreign to us.

Contrary to the USSR, these relationships were easily re-established and were not cut off in the first place. So we are not starting completely from scratch.

ICEBREAKER

Mrs. Boggs. Just as no civilized nation has ever been able to go forward without the study of astronomy, no modern nation has ever been able to really go forward without an adequate Navy. So, could you please give me an update on the status of the Icebreaker?

Mr. Bloch. Well, I should tell you that as you probably have heard by now, or will hear, that a contract has been signed with one Louisiana firm to construct such an Icebreaker over the next few years, between now and 1992 or 1993. The proposal came in within the boundary conditions that we set in terms of total budgets.

It's a ten-year lease on our part with an option to buy at the end of the 10 years. We are looking forward to having that available in due time.

A press release—I think you have it in front of you—was released this morning.

Mrs. Boggs. Thank you very much.

Mr. Bloch. We will autograph that release for you.

Mrs. Boggs. Peter, thank you, as well.

Mr. Bloch. He's the brunt of the effort, as we know very well.

Mrs. Boggs. We are very grateful to all of you. Forgive me for taking so much time, Mr. Chairman.

Thank you.

Mr. Traxler. Mr. Atkins?

Mr. Atkins. Thank you, Mr. Chairman.

ASTRONOMY

Mr. Bloch, I am particularly mindful of a compassioned defense of astronomy that was given by Dr. Good a brief time ago, and at the risk of seeming to become a cropper of her wisdom, which is far more vast than mine, I would like to ask you some questions about our expenditures and plans on the Laser Interferometer Gravitational Wave Observatory, the so-called LIGO, that calls for a $192 million expenditure over four years.

As I understand it, it's a very esoteric piece of equipment that will be restricted to a somewhat limited number of people.

And while certainly Dr. Good is correct that every civilization has always had some focus in astronomy, of course, for 90 percent, or better than 90 percent of human history, it was the naked eye.

There were no expenditures required, but for astronomers today there is an infinite cost for the instruments that they could design that would get us greater and greater volumes of information.

And it just would seem to me in looking at this, and perhaps I am looking a gift horse in the mouth, as I represent the MIT community, but we are dealing with a situation where this is an extraordinary expenditure of money at a time when we have immense needs that people have talked about in the education area, immense needs on some biological sciences where we are really worried about the future of the planet, and immense needs in terms of industrial competitiveness.

And it would appear that we are embarking on a course that is, while important, perhaps not a priority when looking at those other expenditures.

Mr. Bloch. Well, I need to make a few comments.

First of all, let me just remind you that less than $200,000,000 is a bargain compared to the SSC, which is also limited to a few researchers.

We are dealing with medium kind of projects in NSF. That is point one that I wanted to make.

Point two, yes, it's true that like a telescope LIGO is restricted essentially to the use of one community, however, that community is a very important one in attracting people to science and engineering careers, no matter what they are going to do later on, if they become astronomers or not.

Third point, it's the fallout from many of these activities that find their use in instrumentation in many other areas. For instance, some of the astronomy fallout in the past few years found its use in medical instruments that we are using today in hospitals around the globe every day and every hour.

One cannot just narrowly look at such an endeavor on how it fits in with one particular discipline, but also one has to look at what else it does in terms of furthering the total science and engineering careers, as well as activities.

And the fallout is very great, especially in the instrumentation area, and what we are talking about here is not just one homogeneous instrument but this instrument is made up of a lot of smaller instruments, each one very important in its own right and in other fields.

So look at it as an investment in a broader range of activities.

Also, I think it's very important that we look at many of these communities, like material science, astronomy, that you mentioned, physics and so forth, as the training ground for people.

Many people that start off as astronomers don't stay in astronomy, or start off as physicists don't stay in physics. They move on to engineering fields as an example, other science fields which make a direct contribution.

EDUCATION AND RESEARCH AND LIGO

I think this linkage between education and research is not well understood, and it's probably one of the great strengths of our system.

In our system, we are not just in a separate research institution, but we do research in an educational institution; namely, in our universities and colleges, and that is different from what other countries are doing, markedly different.

I think the benefits we can receive from that, I don't think we know what they really are. But you can see it from time to time on a case-by-case basis very clearly.

Let me just remind you of one other thing. One industrial outfit called AT&T, or Bell Laboratories, to be specific, devoted some time, 20, 30, 40 years ago to radio astronomy. They had no right to be in radio astronomy, but they were in it because of the fallout of radio astronomy on the rest of the field.

And in fact, some of the fundamental Nobel Prize work was done by Bell Laboratories, and was not done in any university.

So you never know where lightening strikes.

Mr. Atkins. Well, there isn't anything that you have said that I could disagree with.

Mr. Bloch. You have probably read it in every book, by the way, too.

Mr. Atkins. I am sure that we could spend a lot of money on an instrument to try to figure out where lightening will strike. And it seems to me that the question is not about whether you expend this money on research, or whether you expend it someplace else, but rather how you expend the money within the research dollar.

And I am particularly troubled by your—we have now established the SSC as the benchmark.

Mr. Bloch. No.

Dr. Good. No, No.

Mr. Atkins. That that's expensive and anything compared to that is cheap.

Mr. Bloch. I didn't quite mean it that way.

Mr. Atkins. Well, I know you were saying it facetiously, but still, in my book, $192,000,000 is an extraordinary amount of money.

And while I appreciate the fallout that you have on things like medical instrumentation, if you dump $192,000,000 any place in the research area, you are going to have significant fallout.

And I would venture to say that the fallout that you get in a number of other ventures arguably would be substantially greater, that the fallout is somewhat incidental in this case rather than directed. While certainly, having this kind of instrument creates an attraction for researchers as a training ground, you may want to look at investing that money directly in education. To say the fallout is indirect is to say that there will be some people who will start in astronomy and then switch over to electrical engineering or whatever. It's hard, at least in my book, to justify the expenditure based on that.

LIGO AND EDUCATION AND RESEARCH

And I have a sinking suspicion, and I will have to confess that I really don't begin to understand the politics of science, but that the good part of the pressure for this particular instrument comes from two things.

One is the fact that you said it wasn't a homogenous instrument but rather a number of small discrete instruments pulled together. That creates enormous pressure in terms of a large number of companies that have an interest in investment.

And the second is that the researchers that we use tend to be, and the astronomers tend to be, some of the people with the greatest prestige in the Academy. The prestige that those people have from the work that they do tends to give them a significant claim, particularly within a scientific context, for resources.

And I guess my question is, assuming that we do not participate in the LIGO, and that we are talking about two parallel instruments that will be constructed by the European community, what is the great loss that we have?

What is the research that we cannot do with just two instruments?

LIGO

Dr. **Good**. Let me speak to this, because the board has spent a lot of time on this item. So let——

Mr. **Atkins**. I suspect as much.

Dr. **Good**. Let me tell you that it has been delayed a number of times. The reason that it was delayed was not because we did not believe the research to be done was appropriate, because it is, and I will get to that, but we also wanted to be sure that the Foundation's role was appropriate. One of our problems is that we are expected to do everything from solve——

Mr. **Traxler**. It sounds like this committee's jurisdiction. We know exactly how you feel.

Dr. **Good**. We are expected to solve the education problems from birth to Ph.D. We are expected to be involved in research problems across the board except perhaps in the medical field, and a few others.

One of the fundamental challenges that the Foundation does have even in its charter is that it is, indeed, the only agency in the United States Government which has the role of ensuring that our people are at the cutting edge of science.

That is the issue with respect to this piece of equipment. Is that piece of instrumentation and the work that those people are doing really an experiment which is going to move the frontiers of science beyond where we are today?

Now, we don't spend that kind of money in the Foundation, I can assure you, lightly, because you are correct, it is a large amount.

The astronomy community alone could spend the entire Foundation's budget legitimately. We cannot allow that, of course.

The issue in this case is that the Board looked at that for a very long time and the decision was not based seriously on any of the issues that you brought up. It was not based on politics. It was not based on the fact that it is at MIT. It was not based on the people who were writing it, but it was finally based on our belief that, they had brought the science to the edge and now need to move science beyond what we know.

This is the best next experiment to do. Most of the equipment and the companies that provide equipment could really hate this kind of a program, you are wrong about that, because the researchers ask them to modify it, to change it. They want twice the value of what they have to pay for. So it is not something that most instrument manufacturers want to have anything to do with.

Most of it is designed and built at home anyhow. It is a customized kind of thing. So, the issue really is, and the reason for putting that one at the top of the priority list at this point in time is, that the science to be done will, indeed, be changing our outlook. How we think and what we see will be changed by that experiment. And that is why we should either do or not do that experiment. And I don't believe we want to tell the American public that we cannot participate at the cutting edge of where science is. That is what the issue is.

Mr. ATKINS. The question I asked is what is lost in terms of the research capability with two—absent the four——

Dr. GOOD. The two on the other side will simply be the ability to test the experiment. Are you aware of the story that came out on the big star, the super nova?

The only reason that we really knew was that that truly was a super nova was that you had a device turned on in Europe, and one in Canada, and one in the United States.

This experiment requires that kind of verification. If we don't have the instrumentation turned on in several places, we cannot tell whether what we have seen is real.

Mr. ATKINS. We are talking about the difference between two machines and four machines, as I understand it.

Dr. GOOD. Those are detectors. These are not machines at these other places. Very different things. Very different things.

LIGO

Mr. ATKINS. I appreciate that. Two pieces of equipment.

Dr. GOOD. That is correct. The physics require seeing it at different parts of the globe, or we cannot tell whether the science is correct or not.

Mr. BLOCH. Let me attack it from or answer you from a slightly different view point. I think Dr. Good made the point very well that this program is not new. It has been around for many years, okay, and we have been delaying and delaying it for a number of reasons.

First of all, some of the technology was not quite there, but secondly, also, you know, we couldn't fit it within our budget, and by the way, the problem that we also have is instrumentation or equipment, whatever you want to call it on the one hand and support of people on the other.

Unfortunately, people need instruments in order to do their research. This happens to be a bigger one; that is why it catches your eye.

But you should know that we are spending a large amount of dollars every year on instrumentation, small instrumentation, medium sized instrumentation. This happens to be a big one, and, therefore, it catches your attention.

But how do we move forward in these scientific areas? One answer could be, we don't. And I think that would be a major kind of mistake for a country like the United States to give up on some of these forefront sciences, because in the end, it detracts from our economic competitiveness. In the end, it detracts from our capability of having a technical work force in place, because some of these big instruments, and by the way, I am not in love with big instruments, because of what they cost. But many times they are needed, and they are necessary.

But some of them also are most of attraction for our students and we shouldn't forget this.

Mr. ATKINS. If I could just quickly follow up, and then I will end this. But I just—I am in an odd position. It is essentially in my district, and I should probably be happy and shut up about it, but it truly does bother me, because I see virtually, not at Harvard and MIT, they have virtually substantial access to capital, but for almost all of the research institutions and the undergraduate institutions in this country there is a desperate need for equipment, and I appreciate that you finance a large amount of that equipment.

Mr. BLOCH. We are doing a lot of that.

Mr. ATKINS. But if we are talking about our competitiveness and scientists, it would seem to me that putting $192 million in those areas would return vastly more in terms of what we need, and in terms of where we are as a country.

I see where we are going in Massachusetts. We are going to have the wonderful things like LIGO, and the Japanese will have spent all of their money on advanced materials, and there isn't a market for LIGO. And it will be wonderful and we will be sitting around virtually naked and cold, appreciating these things, while the Japanese will probably own the mortgages on them. And that troubles me.

I mean, at some point I think we have to appreciate the limits of our ability to finance this kind of equipment when it goes to a tiny number of scientists.

So, if you want to respond, and then I will turn the time back to the Chairman.

Mr. BLOCH. Let me respond. It is a balance that we are talking about. It is a balance between supporting people and supporting instruments.

By the way, you should know that there is another fairly expensive instrument that has been in our 1990 budget and will be in the budget for the next three, four years, and that is the high magnetic field laboratory, to replace one that happens to be at MIT right now, okay?

By the way——

Mr. ATKINS. I was going to get to that, but I will spare you.

Mr. BLOCH.. Might as well get to it, but let me make the point. It will cost $100 million. At the time when the first one was constructed it cost $20 million. That is how the cost of science has increased. That instrument is useful for everybody who does materials work and much materials research in your district alone depends on that instrument. I don't know exactly, but I suspect it is very much.

So, we have to have some capabilities that are very expensive, and some of them are more directly applicable to the work that is going on in industry today, and some of them are less, but nevertheless, both of them are required if you want to move research forward and if you want to move science and engineering forward, and believe me, we had to undergo a lot of soul searching before we put the LIGO instrument in our budget request.

We delayed it for a couple years, probably where we should have. But sooner or later, you have to bite the bullet.

Mr. ATKINS. I will just suggest, fortunately, it is a lot cheaper to search your soul than to search for a black hole.

Mr. TRAXLER. Well, we are at that point in the day in which we have to consider nourishment, and it is a very important part of the day, I might add.

We will reconvene at 1:30? That will be helpful.

See you all at that time.

AFTERNOON SESSION

ECONOMIC COMPETITIVENESS OVERSEAS

Mr. TRAXLER. The committee will come to order. Here is the $64,000 question, the one you have been waiting for.

Mr. BLOCH. I can hardly wait.

Mr. TRAXLER. The wheel is spinning. You have been promoting and advocating increases in the NSF budget for many years, and you constantly stress the battle for competitiveness with our overseas competitors.

The question is, What is the score? Who is winning? How are we doing? How is the home team doing?

Mr. BLOCH. When you say winning, Where is the question? I mean, let me take it in pieces.

Mr. TRAXLER. We might be here all afternoon with this answer, you know. It is a book, isn't it? Is it your first book or second book?

Mr. BLOCH. It is the unwritten book. It is the unfinished opus. I need to dissect it for a minute and look at how well are we doing in terms of research, scientific results, engineering results and so forth, and I must say in that area, we are doing well.

However, the gap is narrowing. It was a big gap five years ago and certainly 10 years ago. It is certainly narrowing in some research areas that are very important to economic competitiveness.

We talked a number of times this morning or mentioned a number of times about materials, and in that area it has narrowed.

I think we need to be leery about that and concerned about it. In some of the areas, some countries have overtaken us in the processing areas, for instance, in some of the technologies like semiconductors, no doubt in my mind that the Japanese are winning and, are overtaking us.

It depends where you look. You have to say one thing we are good in the basic research area. We are not as far ahead as we have been at one time. The investment that the other countries are making is increasing.

I don't think we are completely convinced yet that Europe has changed in a significant way. And they have put in place some cooperative efforts between industry and universities that never existed before, and by the way, not just on the country basis, but on a pan European basis and that should give us some concern.

The other area where I think the gap is narrowing significantly is in the attraction of people to the sciences and to engineering. We had at one time, a tremendous lead. That load is narrowing also.

In many of the areas such as manufacturing in direct technology, no doubt about it, we are pretty far behind in more ways than one. So it is a mixed picture.

DOUBLING OF THE NSF BUDGET

Mr. **Traxler**. It is commendable that the prior administration, the Reagan Administration and now the Bush Administration, want to double the NSF budget. That was, I think, originally intended to be a five-year initiative, which has been slowed in the Congress and this subcommittee because of ongoing budget constraints.

What I am interested in is, tell us what the base was that the double was to take place from? Was it the $1.2 billion or the $1.3 billion that we are doubling?

Can you recall?

Mr. **Bloch**. It was $1.6 billion. It was at $1.6 billion in 1987, moving to $3.2 billion by 1992.

Mr. **Traxler**. Okay. If the 1991 request is fully funded, that would be a hopeful prospect, but tell me how long will it take, assuming similar increases in the future, to double NSF's budget.

Mr. **Bloch**. If it is fully funded and if we are getting funding along similar percentage fundings in the future, it will be the middle of 1993.

Mr. **Traxler**. Okay.

Mr. **Bloch**. So, we are essentially 18 months to two years behind the original plan.

SCIENCE AND ENGINEERING EDUCATION

Mr. **Traxler**. The 1991 request for science education is up nearly 23 percent over the 1990 appropriation. That represents the best increase for Science and Engineering Education since this committee saved that program in 1985 and 1986.

The increase is big. The problem perhaps is even bigger. The increase is largely in the undergraduate and graduate programs of universities and colleges, rather than at the precollege level. In fact, the increase in the teacher preparation enhancement area is 10.6 percent, which is less than the overall increase for the Foundation.

This subcommittee has made every effort to concentrate what increases we have been able to scrape together over the past four to five years in the precollege area. It is the sense of the committee that unless you have kids coming out of the high schools who want to go into science, it does not matter how much money you spend on undergraduate and graduate programs, bearing in mind that you told us last year that 50 percent of the doctorate candidates are foreigners, and I think around 60 percent or 65 percent are foreign born.

So, it doesn't matter, in our judgment, how much we are spending in undergraduate and graduate programs if we are not enlarging the pool that is available to draw from for those programs.

What do you think of that?

Mr. BLOCH. Well, I agree partially and I disagree in some respects.

Let's talk about it for a minute.

First of all, you are right. The precollege increase is about 18 percent. The graduate fellowship program is about 20 percent. But don't forget, that is on a different base.

On the one hand, we are talking about $165 million and on the other hand we are talking about $35 million. So we are talking about a different, absolute dollar amount.

The second one, and we have talked about that before, is that unless we attract people while they are in their precollege studies, it is too late to start when they are already in college or in the university. I am not arguing that point at all.

But I sure argue the point that we should depend on the influx of foreign citizens to the U.S. to fill the quota that we need in order to maintain our own science and engineering base in our industries because it is not a dependable source for people. It can be cut off tomorrow, and by the way, in some countries that has happened.

I think we have to do it right, with our own people. With graduate programs like the fellowship program. Just fixing one part of the pipeline without regard to the other part is shortsighted. We have to focus on the total of the pipeline.

Mr. TRAXLER. Well, we sure do need to see more; don't we?

Mr. BLOCH. No doubt about it.

Mr. TRAXLER. I just want to tell you an interesting conversation I had with a very proud father over the recent week at home. He was pleased that his son was at a midwest university majoring in chemical engineering. But, he said what his son had told him was that as an undergraduate, he has noticed that in examinations, the foreign students are generally knocked up about a half a grade, putting them at a 3.0 or above, while American students don't receive such consideration. I wonder why that is, if indeed that were, a fact.

Is that to make sure they get into graduate school? That is an observation of a student.

Mr. BLOCH. That might be an observation of that particular student. I have never heard that.

Mr. TRAXLER. That was my question.

Mr. BLOCH. But, I don't think you can apply it across the board.

Mr. TRAXLER. All right.

Mr. BLOCH. Maybe the student was about to flunk out; I don't know.

THE PIPELINE ISSUE

Mr. TRAXLER. I remember those days. We were recently, in conversation with various people, told that the United States is graduating about the same percentage of Ph.D.'s in the sciences relative to the total pool available as it was 10, 15, 20, maybe as much as 25 years ago.

Also, some other people, mostly at AAU, suggested to us, that, in fact, the percentage has been dropping against the total pool.

What do you think is the right answer there?

Mr. BLOCH. Well, both can be right, but I am completely sure——

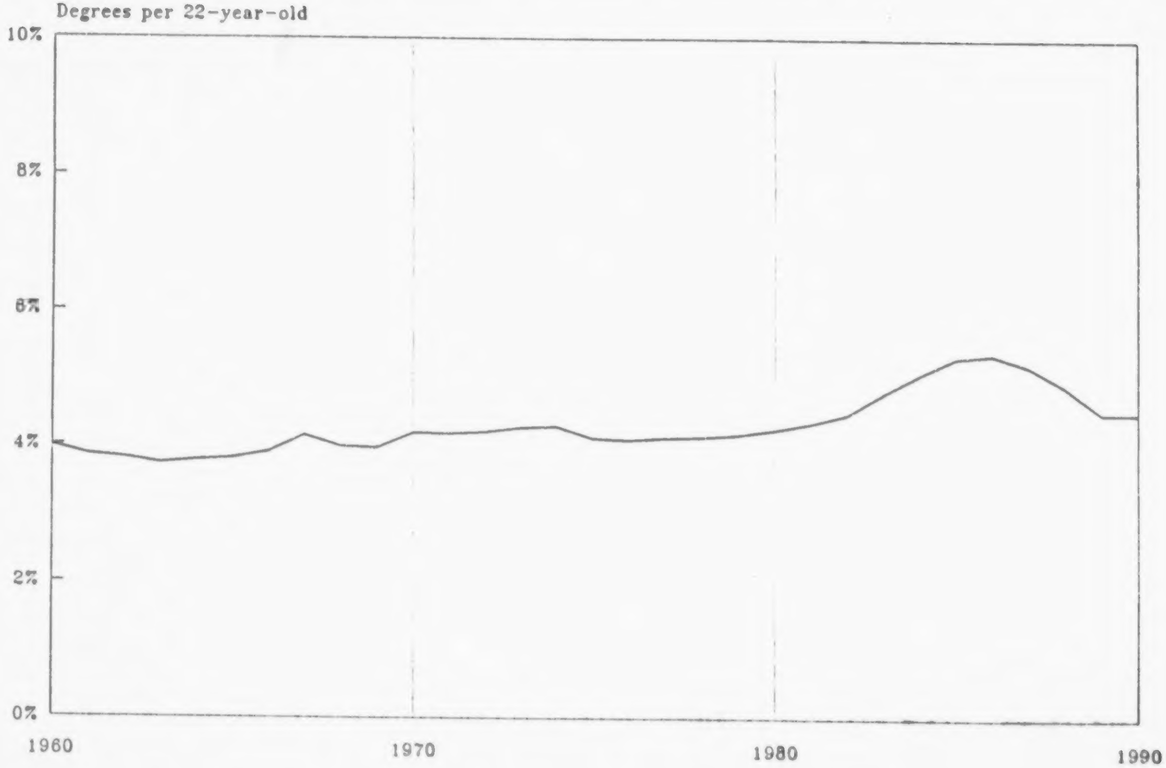
Mr. TRAXLER. I was kind of curious about it. I thought maybe you had come up with it.

Mr. BLOCH. I am sure it could be right in certain disciplines, you know. Both statements could be right in certain disciplines.

But let me make one comment. If you look at the undergraduate population on this chart, and we just agreed that undergraduate degree production in the natural science and engineering is dropping as a percent of the total undergraduate degree production, which is a bothersome observation. We have seen that in 1987, and again in 1988. Those are the last two data points that we have.

[The information follows:]

Participation Rate for 22-year-olds in
NS&E Bachelor's Degrees



Mr. **Bloch**. It is not just a blip that we are seeing. And, if you go one step beyond that, you can also tell where it is dropping. It is dropping in mathematics; it is dropping in computer science; and it is dropping in engineering, as well as in some of the other disciplines, but to a lesser extent in some of the other ones.

That is one point that I think that can be made.

The other thing that I wanted to point out is that the attraction rate has stayed fairly constant, the attraction rate being defined as the number of people that are going into natural sciences and engineering as compared to the total 22-year-old population.

That has been staying fairly constant. That does not say anything about the production rate at the end, because there is some leakage during college stays, certainly; that is an observation we can also make.

Mr. **Traxler**. The President's recommendation saw NASA receive the biggest increase in our appropriation bill. They are in for a 24 percent increase. About $300 million of that increase is new money for the Moon-Mars initiative, also known as Human Exploration Initiative, HEI. One of the arguments that the proponents of this program make is that it keeps the United States competitive in the national arena in several ways. But, one of the main things that we talk about is that this program will help to significantly increase the number of science Ph.D.'s.

It is sort of a spinoff in that regard. But when you set out to spend anywhere from $200 to $600 billion, let's say a half a trillion over 20 to 25 years, total dollars, that would be a minimum, of course, the question that arises is what if we were to dedicate some portions of that to science education and basic research and the National Science Foundation? Would we get a bigger bang for our buck in this production of Ph.D.'s? Can we stimulate more interest in science with increased scholarships and graduate stipends and doing more at the undergraduate level, or at K-12 level?

Mr. **Bloch**. Well, I think so.

Let me elaborate on that answer a little bit.

First, these programs are being undertaken primarily for their own reason, and they should be judged, if they should be funded based on the rationale about why we undertake these very expensive kinds of programs.

I have been criticizing DOD for not paying its fair share when it comes to educating the people they needed over the last few years when they have the majority of the dollars that was being spent for our Federal R and D. I really felt that they were falling down on the education part of their obligation.

They need Ph.D.'s, they need B.S. degree people. The same can be said about NASA. NASA has not spent as much money as they could or should have on the education of the people that they count on and depend on.

I will give you one example. We have a graduate fellowship program that at any point in time supports about 3000 graduate fellows a year. NASA has one also which supports about 400. That is quite a difference.

We are supporting about a thousand new ones every year. They are supporting new ones, about 120, 130 a year. About 10 percent with a much bigger budget than, obviously, NSF has. I will say right away NSF has a very special obligation in that particular area.

But still, NASA could contribute more of its money elsewhere, like NSF, in a direct way to effect more production of Ph.D.'s as well as undergraduate degrees.

THE PIPELINE ISSUE

Mr. **Traxler**. I neglected to mention when I was giving you some illustrations that where some of the money could be utilized was with the construction of facilities and the purchase of equipment for science buildings on our university campuses, a need that you addressed previously, and we will talk about that later.

Mr. **Bloch**. Yes, I am sure we will.

Mr. **Traxler**. We always talk alot about those things.

Mr. **Bloch**. Let me just elaborate a little bit more on NASA.

I would like to introduce this into the record. It is a chart that shows the investment of $10 million into various departments, and you see a whole range of departments from DOD, NASA, NIH, DOE, two points to be made.

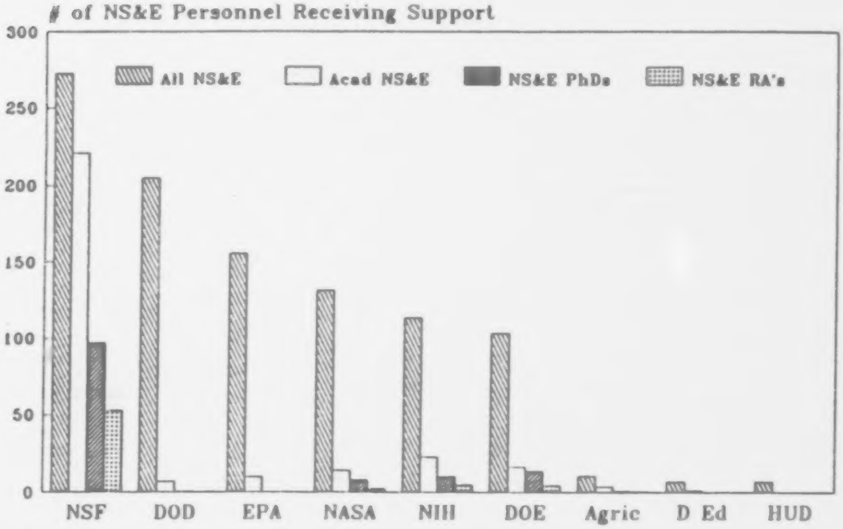
Obviously, NSF invests more in people and education than all the others. You see that on the first bar of the graph. But the other point I want to make is that we are spending most of our money in academic environments, and it is the academic environment that educates the people, whereas some of the other departments like NASA, for instance, spends very little on academic and support to Ph.D. scholarships.

That shows pretty graphically the leverage that the dollars have when spent in the various departments on education and production of people.

Mr. **Traxler**. It is an amazing chart. We will include that in the record. Very helpful to the committee. We have been looking for something like that for a number of years.

[The information follows:]

Estimated Impact of $10 Million Budget Increment on Support of NS&E* Personnel by Selected Federal Agencies



* natural scientists and engineers

- This graph depicts the impact of a $10 million budget increment on the number of natural scientists and engineers supported by a number of Federal agencies.
- The results hold for all natural scientists and engineers (All NS&E), academic scientists and engineers (Academic NS&E), PhDs in the natural sciences and engineering (NS&E PhDs), and NS&E graduate research assistants (NS&E RAs).
- These results are based on the relationship between the average number of natural scientists and engineers supported by each agency in the mid-1980s and each agency's overall budget.

BIOLOGICAL, BEHAVIOR AND SOCIAL SCIENCES

Mr. TRAXLER. Turning to some budget questions. Biological, Behavior and Social sciences, page BBS–3. On that page we note in the table comparing the 1990 current plan with the original 1990 request, the subactivity Biotic Systems and Research took a substantially larger reduction than anything else under this Directorate. Can you tell us why there was a 12.2 percent cut in the Biotic Systems compared to anywhere from two to six percent in all other subactivities?

Mr. BLOCH. I think Dr. Mary Clutter will answer that question.

Dr. CLUTTER. Well, it was a matter of the big reduction that we experienced in our budget, and as you quite appropriately noted, we had a big reduction in all of our divisions, yet all of our divisions are sponsoring research that is vital to the progress of the life sciences, biotic, and so biotic systems and resources seemed to take a big hit, certainly all of our divisions did.

Mr. BLOCH. You should know this, Mr. Chairman, that this is really a change from our request. It is not a change from the 1989 budget.

All of these divisions had an increase over 1989. But the decrease from our request, is because our request just wasn't funded.

Mr. TRAXLER. 12.2 just sort of stood out and we were just wondering what the rationale was for it. In other words, you didn't take it across the board?

Mr. BLOCH. No, we didn't.

You know, the other thing is easy come, easy go. You have a big increase on your request and you don't get your request, you get a big decrease.

Ms. TOYE. If I may interject, though, we did, indeed, follow the proportionality language. The things that were in for the largest increase come out with the largest apparent decrease, because they are in the margin, but we were quite meticulous in proportionality language in determining that.

Mr. TRAXLER. Thank you.

Dr. CLUTTER. I was about to add, if you will also notice, that division did get the biggest increase.

SCIENCE AND TECHNOLOGY CENTERS

Mr. TRAXLER. Turning to BBS–31 Science and Technology Centers are displayed. I have a question for S&T centers that really goes to your budget.

You are requesting some $25 million to fund the second class of science and technology centers in fiscal year 1991; is that correct?

Mr. BLOCH. That is correct.

Mr. TRAXLER. And then the first class was funded with 1989 dollars; if my memory is correct, and there were 11 S&T centers awarded?

Mr. BLOCH. Right.

Mr. TRAXLER. Now, looking at the justifications, it indicates that the second class of proposals was received in the fall of 1989. You had originally intended to fund the second class of science and technology centers from fiscal year 1990 funds. That idea was put on hold because of the substantial reduction last year, and the funding of three new engineering research centers.

Is that the rationale?

Mr. **Bloch**. Well, the rationale that they were put on hold was primarily because of the 1990 budget. We had in our request three engineering research centers that we wanted funded out of 1990, but we can't fund those three plus 11 new science and technology centers. We are holding over.

However, the submissions that we have will be funded in 1991. We are not going to solicit a new request for proposals.

Mr. **Traxler**. Did you have a set of proposals the previous year with the expectation of being funded out of the 1990 appropriation?

Mr. **Bloch**. Yes. That was the original idea, to fund them out of 1990 dollars.

Mr. **Traxler**. The current proposals, are they the same proposals as you were looking at for 1990 funding?

Mr. **Bloch**. Correct.

Mr. **Traxler**. Continuing on STC proposals for a moment, you indicate that the site visits to the most meritorious proposals are planned for the spring of 1990. How many site visits will be made this spring, and what do you see as the final number of S&T centers that you expect to fund if you receive the full $25 million?

Mr. **Bloch**. There will be 30 site visits, and out of those we expect somewhere between eight to 11 new centers.

You can't predetermine that, because the centers run differently in terms of the budget that they require. They are not uniform. We didn't say here is the budget amount that you have to meet or cannot exceed. We left it up to each proposal to determine what the budget was that they required.

That is why we cannot be very precise. But I would say, based on our experience before, somewhere between eight and 11 that we would expect to fund with the dollars that we are asking for.

Mr. **Traxler**. Fully funded?

Mr. **Bloch**. Yes, yes. Fully funded the first year.

Mr. **Traxler**. That is the answer.

Do we understand then that over and above the $25 million requested for the second class of STC, an additional $27 million is requested to fund the 11 centers from the first class.

Mr. **Bloch**. That will continue funding the 11, yes.

Mr. **Traxler**. So we are looking at a total of $52 million?

Mr. **Bloch**. Yes.

JOHN VON NEUMANN CENTER

Mr. **Traxler**. Turning then to computer science and engineering on page CISE-5, the justifications indicate that the reduction in the 1990 current plan versus the request for advanced scientific computing included the phasing out of support for the John Von Neumann Center, which represented one of the five super computer centers six years ago.

Has it been six years?

Mr. **Bloch**. Yes. Time flies. They were funded in 1985.

Dr. **Wulf**. This is the fifth year of the so-called phase two centers.

Mr. BLOCH. The solicitation I think was in 1984 for these centers.

Mr. TRAXLER. Well, in any event, there is a lot of institutional memory left around here. That is amazing. As most agencies go, you ask about six years ago and they get a blank look. You can't even get back to the civil servants who remember six years ago, so congratulations.

Mr. BLOCH. Continuity is very important.

Mr. TRAXLER. Congratulations.

Could you tell us why the support was phased out, and, we talked about this last year, what went on in the review that they couldn't cross over the line? Have you thought about a new student center? Or is your decision to stay with four centers instead of six, if you count the center with the NASA computer, of course? What happened at the John Von Neumann Center?

Mr. BLOCH. Well, what happened with the John Von Neumann Center is essentially that the machine that was installed there was an ETA; and that particular manufacturer went out of business, closed shop. It was a subsidiary of CDC that just couldn't make it in the marketplace.

And the machine, without further improvements, was really not a viable, economic machine. In fact, it was not reliable enough with the present state of development to really perform at its own speed.

That was the time reason. The time reason was the ETA Corporation was closing its doors, going out of business, and not being able to continue doing the software development work that was still required. They could not guarantee that the machine could perform nor were they committing for a long-term that they would service, or be able to service the machine.

That was the prime reason for the phase out.

Dr. WULF. Could I add to that a little bit? I am Bill Wulf. I think there are several other things that need to be mentioned.

First of all, ETA systems closed its doors in the middle of the review process, and as soon as that happened, we gave the Von Neumann people the opportunity to revise their proposal. We went through a rather extensive review. We tried to give them every opportunity to compete on a level playing field, if you will.

When everything came down to it, the review committees and so on judged that it was not a viable center to continue. Simultaneously, we had been, as you know, upgrading the other four centers. We actually at this point in time with four centers have twice the capacity that we had with five centers, just a tad over a year ago.

Mr. TRAXLER. How much money was left over from the Princeton Center? Do you recall if you were able to reallocate among the remaining centers?

Dr. WULF. We are spending $8 million this fiscal year, 1990, to phase down the center.

The cooperative agreement actually ends the end of April.

Mr. TRAXLER. But how much money was left, if any, from the Princeton Center?

Dr. WULF. None, really. By the time that we——

Mr. TRAXLER. How do you propose to upgrade the centers, then?

Dr. Wulf. Well, I think the right way to say it is after the proportional reduction was taken from the 1990 request, we had enough money left over to upgrade all of the other centers, and to afford the $8 million for——

Mr. Bloch. Well, correct me if I am wrong, if the center had continued, if it hadn't closed its doors, it would probably have spent in that year another $7 million, so $15 million total.

So you can essentially say $7 million was saved, okay? But at the same time, we also had the reduction in our request that we had to contend with.

NSFNET

Mr. Traxler. In regards to the operation and upgrade of NSFNET, which is as we see on page CISE-6, we are looking for a 41 percent increase in 1991. The staff had some discussions during the year with the DOD Appropriations Subcommittee regarding where this networking program was going. We should tell you that those discussions were based on serious concerns from existing networking sources that DOD was heading in the wrong direction with this effort.

Are you familiar with some of those concerns and will we be hearing them again this year, or has the issue been put to rest, or do you know anything about what we are talking about?

Mr. Bloch. I don't know what you are talking about.

Dr. Wulf. We had a conversation here in this office that I think largely revolved around the degree of cooperation between the major agencies involved in networking, which is ourselves, the Department of Defense, DOE and NASA. I hope we convinced you, because it is true, that there is a great deal of cooperation and collaboration, very tight coupling of the activities of those four agencies.

In fact, we have just established something called the Federal Networking Council to officially coordinate those activities.

Mr. Traxler. Well, we may continue this conversation later.

Dr. Wulf. Okay.

Mr. Traxler. Looking at the robotics fundings on page CISE-13, is there any cooperation between this funding and the Telerobotics Servicer in the NASA budget? That is an initiative that we strongly support on this subcommittee.

Dr. Wulf. Not on that specific program. We tend to do the basic research. That is an applied program, as I understand it. But there is no specific cooperation on that program.

Mr. Traxler. We would recommend that to you, that you chat with some of the people at Goddard, and you may find that we don't have to reinvent every aspect of the wheel.

Dr. Wulf. Sure.

COMPUTER SCIENCE AND ENGINEERING

Mr. Green. Mr. Chairman, before we leave CISE, I gather that the computer and information science and engineering directorate took by far the largest reduction under the fiscal year 1990 operating plan, 11.2 percent from the fiscal year 1990 request. And, obviously, that was due in part to our inability to give you the full request last year. We do understand that.

As I understand it, NSF supports about 40 percent of the total Federal funding of basic research and computer science; is that right?

Mr. GREEN. Given the fact that many big Federal programs such as the Earth observing systems under NASA depend on our ability to process data; shouldn't we be giving this area priority?

I keep hearing these stories about the warehouses full of data that NASA has. I gather NOAA has a similar problem with a lot of their material. Don't we really have to be doing more in this area?

Dr. WULF. I think it's the case that many of the important science projects that the country has started are critically dependent upon information processing technology. When you talk about the genome or global change or the seismic studies and so on, they all depend on information storage, our ability to retrieve it, our ability to process it and make it intelligible to the human beings in one way or another.

Computer science, computer engineering, and computational science are the seed corn which let's us do those things. You won't find any argument from me that those are extremely important activities.

Mr. GREEN. I guess then my question is why did it take the biggest operating plan reduction?

Was that again because it had the biggest——

Dr. WULF. Again, I believe it was simply that we followed the proportionate language.

Mr. BLOCH. Let me make a slightly different point. This organization, computer and information science and engineering, is doing a lot of the basic research, but that doesn't mean that the other agencies don't have to address the data problem in their particular programs.

And what you are seeing when you are citing that there are warehouses full of data that has never been used, is essentially a particular program that has a lot of data, but is not making adequate provisions for handling it, accumulating it, digesting it, reducing it, and putting it out for the community to use. You are seeing that.

I don't think that NSF will ever be in a position to change that. That has to be at the source; namely, the program that generates the data.

When that has been formulated, there are adequate provisions for data processing.

Mr. GREEN. Let me ask if you think that the state of the art exists and that that can be done. For example, I guess it was the Advisory Committee on the EOS program that made another interesting analogy. They compared the data that the EOS will be sending back with the total data base of the Internal Revenue Service, which they identified as consisting of 30 trillion bytes, and every three days, EOS would be sending back an equal amount.

Do we really know? Do we have the research, basic research which tells us how to cope with that quantity of data flow?

Mr. **Bloch**. Well, at any point in time, there is a technology available that you can utilize. That might not be the best technology but there it is.

The research we are doing is for answering the questions that you are asking for, 5 years or 10 years or 15 years down the road.

But at any point in time, you are to make use and make do with the technology that you have available.

Mr. **Green**. But I guess I am asking, given the limitations, both practical and dollar wise, of the systems and technology that we have available today, can we in any realistic way cope with that quantity of data?

COMPUTER SCIENCE AND ENGINEERING

Dr. **Wulf**. I think in cases, yes, and in cases, no. For example, the research that we are trying to do on gigabit networking, I think will enable us to at least move that kind of information around, or move reductions of it such as in scientific visualization.

We are doing research in other areas of very high performance computers, particularly some work which has been primarily done at DARPA—I think it's very promising—on massively parallel computers.

On the other hand, I think the generic answer to your question is no, there are lots of areas which need additional attention. Scientific data bases is one that I am very concerned about.

Mr. **Green**. Last year on page 278 we discussed the resources being made available to parallel computing and the questions of priorities for funding for hardware versus software; and I think it was indicated at that time that you place a strong emphasis within the computer directorate on software.

Does that continue to be the case?

Dr. **Wulf**. That is absolutely the case, yes, sir.

Mr. **Green**. Which of your centers are focused on parallel computing?

Dr. **Wulf**. There is a science and technology center, primarily centered at Rice University in Texas, but also involves Cal Tech, Los Alamos; and Argonne, and to a lesser extent the University of Tennessee and Syracuse University now because of some personnel shifts, which is entirely focused on parallel processing.

Mr. **Green**. How do you feel that is going?

Dr. **Wulf**. I just received a draft report of a site visit, an overview type site visit yesterday, and it's very, very complementary to the center.

Mr. **Green**. Thank you, Mr. Chairman.

Mr. **Bloch**. That is one of the science and technology centers that we funded in 1989.

Dr. **Wulf**. Right.

ENGINEERING RESEARCH CENTERS

Mr. **Traxler**. Turning to the Engineering Directorate or Engineering Research Center funding on Page ENG31, you tell us there are three new ERCs in fiscal year 1990. What are those?

Dr. **White**. We have three new centers: one in data storage systems at Carnegie Mellon University; another addressing geometrically-complex field problems at Mississippi State University; and one in interfacial microbial process engineering at Montana State University.

Mr. TRAXLER. Since we were here 12 months ago, which centers have been put through the three-year review process and are there any recommendations pending before the Board that may cause the Foundation to withdraw funding for any of the centers that are under review now?

Dr. WHITE. We have had two classes that have completed the third year critical review. In the first class, two of the six were not renewed at Santa Barbara and Delaware.

In the second class, all five were renewed.

Because of timing aspects related to one of the centers established in the third year, only two are under evaluation this year. They are at UCLA and at Colorado. The decision has not been made for these two.

At this point, all we can say is that out of a total of 11 that have completed the third year site visit, two of 11 were not renewed.

Mr. TRAXLER. On Page ENG34, you tell us that ERC program increased in 1990 some $5.4 million, and that funded three new centers. Was that sufficient to fund all three of the centers for a full year?

Dr. WHITE. Yes, sir. It's not sufficient, however, to provide resources for the existing centers. So essentially all of that money went to the creation of three new ones.

Our request last year included monies to increase the support of existing centers. As you know from the National Academy report that you referenced earlier, a major concern was the strength of the existing centers.

That is why this year our request is to strengthen existing centers. We do not plan on creating new centers with the fiscal year 1991 budget.

Mr. TRAXLER. Yes. You are looking for a $7.5 million increase for ERC. That is in response to an academy study, I take it?

Dr. WHITE. Yes, sir.

Mr. TRAXLER. When you say upgrading, does that mean working properly, or are you simply talking about upgrading them?

Dr. WHITE. We will be strengthening them. Money will be distributed on a competitive basis as opposed to a formula allocation. Budget constraints in the last three years have resulted in some centers being funded at a "bare bones" level.

The last two classes that we established, in particular, were funded very much at the margin. That would include the four that we established with 1988 and 1989 funds, and those were Wisconsin, Minnesota, Texas A&M, and North Carolina State University.

[The information follows:]

NSF FUNDING FOR ENGINEERING RESEARCH CENTERS CLASSES OF 1988 AND 1989

	Fiscal year—	
	1988	1989
Class of 1988:		
N.C. State University	1.60	2.08

NSF FUNDING FOR ENGINEERING RESEARCH CENTERS CLASSES OF 1988 AND 1989—Continued

	Fiscal year—	
	1988	1989
University of Wisconsin	1.50	1.95
Class of 1989:		
University of Minnesota		1.52
Texas A&M University		1.50

ENGINEERING RESEARCH CENTERS

Mr. Traxler. I guess the question is, did you have too little resources for all of these centers to begin with?

Dr. White. We did not have too little resources to establish them. As you know, you cannot go from zero to full scale steady state operation in a center, either overnight or in one year.

To ramp up the Centers, as we were able to do for the first two classes, would require additional resources; the resources have been insufficient to do that for the last three years.

We need to recognize the fact that they have now matured to the point that they could spend increased resources wisely and have demonstrated their ability to convert that into meaningful research results.

Mr. Bloch. May I comment on the series of questions?

Mr. Traxler. Please.

Mr. Bloch. When I came to NSF, I was a member of the task group, the National Academy of Engineering, that proposed the establishment of these centers.

At that time the number that we had and that we dealt with were something like 25 centers, total, in the United States, and $4,000,000 per center.

If you look at the $4,000,000, and the 25 number, that hasn't happened, obviously.

On the other hand, I must tell you that we did not contemplate in that committee the level of contributions that would be made by state, universities, or industry. And while it's very true that the centers have not been funded to the original goal of $4,000,000, a large number of the centers have been able to attract monies from other sources.

And I consider that, one, a good sign, because industry only spends money if they think they get something back for it. So, it's really a vote of confidence in what the centers are doing.

And secondly, it puts some of the centers a little bit on notice to do some shopping around. And I don't think that hurts in general.

While we didn't really follow through with the original concept, many times we made the trade offs in adding new centers because of the funding problems.

But having to rely on other sources, I don't consider to be a negative. In 1991, as you know, we are not going to establish any new centers. What we want to use this money for is essentially for beefing up and helping the centers that are in existence.

We also can expect and must expect that the centers continue to attract funding from other sources. I don't consider that a negative. I consider that a positive.

GLOBAL CHANGE DATA MANAGEMENT

Mr. **Traxler**. All right.

Turning to GEO-1, under Geosciences, and Bob Corell is here, and you serve on the Committee on Earth Sciences, Office of Science and Technological Policy, Federal policy for Science Engineering and Technology, and you show up as the vice chairman, and we are delighted with that.

We think that is a good choice; I think you put out an excellent publication. It's very helpful to us, and we know that your work is going forward and that you are not finished.

Dr. **Corell**. Yes.

Mr. **Traxler**. Well, you were also involved with that committee's data management subgroup, if I recall correctly.

Dr. **Corell**. That is correct.

Mr. **Traxler**. And what are your views, and you can tell us what you think on overall interagency, or even if you want to, though, in the international data management means for global change research. How are we doing there?

Dr. **Corell**. As I think we discussed last year, we established an interagency working group on data management for global change, and it does involve all agencies who have both potential for contributing to the data base, as well as the user requirement data base.

So it includes all 7 agencies representing the CES Working Group on Global Change Research that Erich mentioned in his opening. It's been in effect now for about a year and a half, and we have gone through several phases, the first of which was to test the idea that a nationally integrated data management system for global change research has the potential for working.

We developed what we call the directory test, literally went out and found a good number of the directories that would be used in the data base program for a global change effort. We then began to massage those to see whether or not we could access them and move the directories across large distances and across barriers that heretofore had been difficult to cross.

That experiment, which was conducted last summer, worked out quite well. We obviously learned a lot. We found out the points that needed to be addressed, and we then moved on to the second phase, which is to test the large data base requirements that you mentioned a few minutes ago by using the architect data bases as a test bed.

There are a number of data bases in both this country and abroad, and we are now in the phase of trying to test out that idea.

The data base architecture is what we call a village architecture. That is, that we maintain the data bases close to their source of generation at the program level, like a WOCE or a TOGA program, so that there is ownership, a lot of caring about data quality.

At the same time, we maintain an over-arching strategy and structure, and of course all the necessary language. This is to avoid some of the problems that have occurred with the large centralized data bases where you get into some very, very serious difficulties.

I would say the jury is still out. We have a long way to go. We have a lot of work to do. Our target is to have this up and running in the 1993, 1994, 1995 time frame.

In order to do that, the agencies all have had to put budget requests on the table in order to build that data base management effort. NASA obviously is one of the major players. One of the conditions that we set on our management of the global change program is that data management should not be treated as it has been done in many cases in the past.

Now, when budgets get reduced, the data management often suffered and it has not been handled very well. We have made a commitment to ourselves and to the Congress that we are not going to do that on this program. We are going to maintain a balance as we have to adapt to budget requirements.

GLOBAL CHANGE DATA MANAGEMENT

As you may know already from talking with NASA, in the EOS program, roughly 40 percent of that request is for data base management and the necessary systems to accommodate it. That's a very large percentage of the programs.

Historically, hardware runs 60 to 70 percent of the total program costs. Hardware in this case is more like 40 percent and 40 percent is for data management.

The other 20 percent is supporting the science program itself. Those are rough figures, and when you talk to NASA, you can get those tuned finer.

And then each of the agencies has put in their own contributing part, and you can see that in the break-out, their component data management.

For example, in NSF, our effort is to fund the data management requirement at the user level, to be certain that those users have access to those large data bases, have the hardware necessary and the local site access to the systems. And as you can see here and as you will see in the future, that is going to cost a fair amount of money.

So I would say we are making progress. I think we have the machinery in place.

Mr. **Traxler**. Where does EPA fit into this? That is the agency charged with the environment, and I am curious as to the role that they play, if any.

Dr. **Corell**. Well, they do. As you can see in the crosscut table towards the middle of the CES documents, there is a science program, largely very basic fundamental earth science; and EPA has a modest research program that contributes to it.

As you can see, the budget request is about $26,000,000 in 1991. It's up from about 13,000,000 million.

Mr. **Traxler**. They are the least contributor of all the agencies.

Dr. **Corell**. Yes. They are the smallest contributor. But their program, as you already know, is very heavily aimed at mitigation and adaptation technologies. That is a very important part of our national responsibility, but it's not a part of the science program.

Mr. TRAXLER. How are we going to access the information that DOD has stored for years and accumulated for years that gives us such incredible amounts of data? Are we going to get into that?

Dr. CORELL. I think so, more so than——

Mr. TRAXLER. I mean, it will be a terrible waste if they don't.

DOD AND GLOBAL CHANGE

Dr. CORELL. We have had a number of discussions, and during the past nine months, a lot of that attitude towards the role of the DOD and global change has shifted away from one where their concern had been more in regional research programs.

We have had conversations with them about the data base. A good example is that there is a really good data base of environmental information about the Arctic. Those are now becoming more open and available to us.

The scientific community is getting access to those.

Mr. TRAXLER. We need to know what is going on with those currents under the iceberg.

Dr. CORELL. We are making progress. Admiral Pittinger and in particular the Navy have been very helpful in opening up some of those——

Mr. TRAXLER. Who do you talk to in the Congress on these matters? You mentioned the Congress earlier, and I was curious who you talk to, who do you discuss this with?

Dr. CORELL. Well, there have been oversight hearings on the global program from the Budget Committee.

Mr. TRAXLER. The Budget Committee?

Dr. CORELL. Budget Committee, yes. We have had discussions with the Budget committee.

One of the interesting things, when we first published this document——

Mr. TRAXLER. How much have they appropriated to you lately?

Dr. CORELL. Well, it's an interesting thing.

Mr. TRAXLER. Never mind. They are a part of the Congress.

Dr. CORELL. You mentioned earlier your 302B allocation is important. I am trying to help you along.

Mr. TRAXLER. I will introduce you to the people it comes from. Oh, boy.

Dr. CORELL. At any rate, really, the Arms Committee, a whole host of committees. We have held a number of briefing sessions for staff. We have a three-day forum every year that tries to help the staff understand what is happening with the global change program, meet with the scientific community, meet with the agency perhaps to go over the program. The most recent forum was held a couple months ago.

Mr. TRAXLER. We are going to have you back and you are going to give us a special briefing.

Dr. CORELL. We would love the opportunity.

Mr. TRAXLER. Let me see if I have some more specific questions.

Mr. LEWIS. Mr. Chairman, could I submit some questions for the record, please?

Mr. TRAXLER. You sure can.

[The information follows:]

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN JERRY LEWIS

EARTHQUAKE FUNDING

1. CONGRESSMAN LEWIS: **Last year the NSF got a little gift--$3 million--from the Continuing Resolution (P.L. 101-130) to augment your resources for assisting the federal efforts to deal with the Loma Prieta earthquake of October 17, 1989.**

CAN YOU GIVE US A SPECIFIC BREAKDOWN OF WHAT THIS $3 MILLION WAS USED FOR?

ANSWER: The $3 million supplementary appropriation formed the basis for a special program announcement issued jointly by the Foundation and by the U.S. Geological Survey inviting proposals on the geology, geophysics, engineering, communications, and social effects of the Loma Prieta Earthquake. The announcement specified two proposal deadlines: 28 November 1989 and 25 January 1990.

The Subactivity Earth Sciences received $1 million of the supplementary appropriation. In response to the first deadline, the Subactivity made the following awards:

Recording of Aftershocks and Engineering Response Data	$ 190,000
Landslides and Tectonic Ground Failures	80,000
GPS Measurements of Ground Distortions	60,000
Fault Rupture of the Loma Prieta Earthquake	80,000
TOTAL	$ 410,000

In response to the second deadline, the Earth Sciences Subactivity is currently evaluating 33 proposals and expects to make awards totalling $490,000. An additional $100,000 was awarded immediately after the earthquake through the mechanisms of supplements to existing awards and the Small Grants for Exploratory Research program.

The Engineering Activity (ENG) received $2 million of the supplementary appropriation. It funded $1,200,000 in quick response research to collect perishable data following the Loma Prieta earthquake. A total of 115 proposals were received by Engineering in response to the first deadline for the joint NSF/USGS research program. ENG is making awards totalling $1,500,000 with funds transferred from USGS.

The second deadline resulted in the submission of 153 proposals by the research community. ENG expects to make awards totalling $1,500,000 from this second group of proposals. The total spent by ENG for the Loma Prieta Earthquake will be $2.7 million.

2. CONGRESSMAN LEWIS: In fact, if you don't count that $3 million, the amount you have budgeted for your two earthquake activities (engineering and earth sciences) for FY 91 ($24.75 million) represents a slight decrease in overall NSF support for earthquake related research from last year ($25.48 million). In light of the frequency of major earthquakes in the just completed decade of the 1980's (Mexico City, Soviet Armenia, California),

ISN'T IT TIME TO CONSIDER DEVOTING MORE DOLLARS FOR THIS TYPE OF RESEARCH IN THE 1990's?

ANSWER: In FY 89 the NSF earthquake budget (Engineering and Earth Sciences) was $23.34 million and in FY 90 it is $26.32 million, including the special $3 million appropriation. The FY 91 request is $24.75 million. The programs have achieved a great deal during this period of relative government austerity.

Furthermore, we have leveraged our funds since the creation of the National Center for Earthquake Engineering Research (NCEER) in 1986. As required by the cooperative agreement which established it, NCEER has been able to match the $5.0 million annually provided by NSF with funds from New York and other sources.

NSF will continue to seek ways to leverage its funds in the 1990's. We anticipate that opportunities for doing this will include jointly funding projects with various states and the private sector as well as with foreign countries such as Japan. Since earthquakes are a worldwide hazard, we feel that sharing resources on an international level will be particularly promising in the 1990's, especially since it has been declared the International Decade for Natural Disaster Reduction.

3. CONGRESSMAN LEWIS: The $9.5 million for earthquake hazard reduction in the earth sciences subactivity (p. GEO-13) actually goes to fund basic theoretical research into the causes of earthquakes. It funds some very wonderful sounding things like plate tectonics and continental dynamics. In general terms, this money supports the projects of seismologists who want to be able to do one thing well--PREDICTION.
We need many things in Southern California. One of the things we may not need is any additional earthquake predictions. A just-completed review of Loma Prieta incident by the U.S. Geological Survey predicts that "an event of magnitude 7.5 or larger on the San Andreas fault ...is more likely in Southern California than in the Northern part of the state." They also predict that the chance of such an event is 60% within the next 30 years.

GIVEN THE LIMITED RESOURCES YOU HAVE FOR EARTHQUAKE HAZARD REDUCTION, SHOULD WE BE SPENDING A THIRD OF THE DOLLARS ON PREDICTION? DOESN'T IT MAKE MORE SENSE TO PUT A HIGHER PERCENTAGE OF THE MONEY INTO THE ENGINEERING SUBACTIVITY SO THAT

WE CAN FOCUS ON ADVANCED PLANNING AND CONCENTRATE ON THINGS LIKE ENFORCING BUILDING CODES AND STRENGTHENING EXISTING STRUCTURES?

ANSWER: Advanced planning, engineering, and code enforcement are, indeed, important aspects of earthquake hazard reduction. Continued progress in these areas, however, depends upon a continuing flow of new knowledge about the nature and occurrence of earthquakes. Assessment of earthquake hazard requires (among other things) a knowledge of the size, location, and recurrence frequency of earthquakes to be expected. Development of building codes and sound engineering practices requires knowledge of the amplitude, frequency, orientation, and duration of ground shaking likely to be experienced, as well as a knowledge of possible ground amplification effects and resonances. Short-term warnings of impending earthquakes, if this could be achieved, would save many lives and protect critical lifelines. Such knowledge depends on a healthy program of fundamental earthquake research.

The question cites a forecast of earthquake probabilities on a single fault (the San Andreas) in Southern California. There are hundreds of other faults in Southern California where earthquake probabilities are very poorly known. There are other parts of the United States that have experienced large and damaging earthquakes in the past where very little is known of the geologic structures involved or the earthquake recurrence intervals. A balanced National Earthquake Hazard Reduction Program requires a broad-based, innovative, program of fundamental earthquake research including engineering research to provide the new knowledge that is needed to guide both local and national earthquake preparedness activities.

MONOCLONAL ANTIBODIES

4. CONGRESSMAN LEWIS: Your budget justification for the cellular biosciences subactivity speaks of the Foundation's support of research in the field of monoclonal antibodies.

CAN YOU TELL US WHAT KINDS OF SPECIFIC INDIVIDUAL PROJECTS THE FOUNDATION HAS SUPPORTED INVOLVING THIS LEADING EDGE TECHNOLOGY?

ANSWER: Over the past five years there has been a virtual explosion in the use of monoclonal antibodies as tools in basic research in many fields of science and engineering. Examples of projects supported by the Foundation include:

-Use in studies of proteins involved in intracellular traffic in plant cells. This project is directed by Dr. Louis C. Morejohn of the University of Texas, Austin, Department of Botany and is entitled "Molecular and Biochemical Characterization of Microtubule-Associated Proteins" from Zea mays.

-Studies of catalytic antibodies, i.e. monoclonal antibodies that can catalyze chemical reactions as do enzymes. These experiments are still in the realm of basic research. However, if specific catalytic antibodies can be made to carry out desired reactions they could be of great use in production of commercially valuable chemicals.

5. CONGRESSMAN LEWIS: DO ANY OF THEM INVOLVE RADIOLABELLED MONOCLONAL ANTIBODIES?

ANSWER: Many basic research projects involving molecular genetics use monoclonal antibodies as standard tools. A popular method for isolating a specific gene is to introduce a large number of DNA fragments into a large number of cultured cells, and then to identify the cells that express the gene of interest by using a monoclonal antibody that recognizes the gene product. In this type of experiment the monoclonal antibody would be labelled in some way, either by an attached fluorescent molecule or, more rarely, by a radioactive label.

Depending on the particular application, radiolabelled monoclonal antibodies may be used in basic research. Because of the costs and problems of radioactive waste disposal, however, experiments are often designed to avoid the use of directly radiolabelled monoclonal antibodies.

6. CONGRESSMAN LEWIS: IS THERE ANY REQUIREMENT WHICH LIMITS THE FOUNDATION'S SUPPORT IN THIS AREA TO BASIC RESEARCH?

I understand that one of the applications for this exciting new technology is in the field of cancer treatment.

ANSWER: Foundation support for research involving monoclonal antibodies is limited to basic research. Application of monoclonal antibody technology in cancer treatment is the responsibility of the National Institutes of Health, and inappropriate for support by the NSF.

7. CONGRESSMAN LEWIS: COULD FOUNDATION FUNDS FOR THE INSTRUMENTATION AND RESOURCES SUBACTIVITY BE USED TO SUPPORT MEDICAL SCHOOLS WITH THE ABILITY TO APPLY THE RESEARCH FOR THIS PURPOSE?

ANSWER: Funds for the Instrumentation and Resources Subactivity have been used to support competitive grants for the establishment (but not long term maintenance) of institutional monoclonal antibody facilities for basic research purposes only. A monoclonal antibody facility at a medical school for purposes of cancer treatment would not be appropriate for NSF support since NSF does not support disease related or clinical research.

8. CONGRESSMAN LEWIS: ARE THERE OTHER FOUNDATION PROGRAMS THAT COULD SUPPORT RESEARCH OR INSTRUMENTATION FOR RADIOLABELLED MONOCLONAL ANTIBODY RESEARCH?

ANSWER: The Research Initiation and Improvement Subactivity through its Research Improvement in Minority Institutions Program can support basic research involving monoclonal antibodies at qualified minority institutions.

Research on catalytic antibodies has been supported jointly by the Biological, Behavioral and Social Sciences Activity Programs and the Chemistry Subactivity in the Mathematics and Physical Sciences Activity.

EARTHQUAKE SAFETY

Mr. **Lewis**. I have got to run. In the meantime, you missed all my questions regarding earthquake safety, but I will be happy to check with you personally.

Mr. **Bloch**. We will be glad to answer.

Mr. **Lewis**. Thank you.

Mr. **Green**. In this chart you listed $103 million, and then it's broken down in a way that—could you, for the record, give us a chart which shows how that breaks out in terms of your program categories?

Dr. **Corell**. Yes. We could easily do that.

[The information follows:]

National Science Foundation fiscal year 1991 budget request for global change research

	Millions
Directorate for geosciences	84.8
Directorate for biological, behavioral and social sciences	7.1
U.S. Antarctic program	11.1
Total NSF	103.0

Mr. **Coughlin**. I will also have some questions for the record, if I might.

Mr. **Traxler**. We understand. Thank you, Mr. Coughlin.

[The information follows:]

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN LAWRENCE COUGHLIN

RECRUITING AND RETAINING HIGHLY QUALIFIED EMPLOYEES

1. CONGRESSMAN COUGHLIN: Several federal agencies under the jurisdiction of the panels I serve on have discussed their inability to recruit and retain highly qualified employees. The problem is purported to be further exacerbated by the growing demand for highly trained individuals in the scientific and technical fields.

Is this an item of concern to the NSF, and if so, what measures is the Foundation taking to retain a highly qualified technical and administrative staff?

ANSWER: Yes, recruitment and retention of highly qualified employees is of great concern to the NSF. A problem exists for all groups of employees--scientists and engineers, administrative staff, and support staff.

NSF's problems in recruiting **scientists and engineers** are especially serious because we recruit primarily at senior levels. Over the past few years both industry and academic salaries for senior researchers have outpaced government salaries. We have taken a number of actions to respond, including (a) seeking greater flexibility from the Congress in paying benefits to visiting scientists, (b) using the Intergovernmental Personnel Act for high-salaried scientists and engineers, (c) hiring senior individuals who have retirement income from other institutions, (d) providing flexitime and flexiplace options for employees, and (e) encouraging the Federal Government to adopt a more realistic pay system that is based on the marketplace and varies by locality and occupation.

For **administrative** staff, in addition to the last two items above, we have enhanced our college recruitment program by establishing links with many local colleges and universities, developing a recruitment brochure, and encouraging managers to use the Presidential Management Intern program.

At the **support staff** level, we have centralized recruitment and speeded up job offers by establishing a central support staff unit from which managers may select individual employees. We have enhanced recruitment by attending job fairs and making visits to local high schools and community colleges. Our most recent activity focuses on improved presentation of our agency as a "good place to work," via recruitment brochures, clearinghouse information, advertisements for bulletin boards, and other material.

In the last analysis, however, the Federal Government will only be able to compete for a decreasing number of young people if its salaries and benefits are competitive with the private sector, if the work it offers is meaningful, and if its employees are both worthy of respect and receive it for doing important jobs well.

NATIONAL SCIENCE BOARD REPORT

2. CONGRESSMAN COUGHLIN: Earlier this month the National Science Board released its latest biennial study on Science and Engineering Indicators. The Board found some encouraging sign, but also found some continuing weaknesses in our national efforts in science and technology such as:

-- national and international indicators of U.S. mathematics and science performance shows little improvement, despite concerted major reform efforts.

-- too few individuals are pursuing graduate degrees in mathematics, science or engineering.

What is the Foundation's reaction to the Board Report?
How does your FY91 request address the weaknesses found in the Board's Report?

ANSWER: The National Science Board's interpretive summary of the meaning of the data and trends contained in Science and Engineering Indicators is presented in a companion report entitled The State of U.S. Science and Engineering: A view from the National Science Board. In it, the Board cites many signs of strength but also trends that suggest weaknesses in our National research and education enterprises.

However, the National Science Foundation -- and indeed the Federal Government -- cannot by itself assume to address all of the challenges confronting us as a Nation. State and local governments and the private sector have important parts to play.

Nevertheless, the National Science Foundation has a vital role in generating and disseminating new knowledge and supporting education. The FY 1991 Budget request reflects a strategic framework for a significant and balanced investment designed to nurture a close relationship between research and education in science and engineering and, in so doing, improve the Nation's productivity and economic competitiveness.

3. CONGRESSMAN COUGHLIN: One specific recommendation proposed in the report [S&EI-1989] is that students be required to take science and mathematics courses throughout high school.

With the NSF significant role in developing innovative course materials are you seeing an acceptance at local school levels to embark on mandatory, four-year classes in the fields?

ANSWER: Although many states have enacted legislation in the last few years that increases the "number of years" of mathematics and/or science in grades 8-12 required for graduation from high school, few states have specified the additional disciplinary content, if any, that is to be presented in these additional years. Recognition of that shortcoming is leading to several important efforts with national implications. For example:

- Professional disciplinary societies, state educational agencies and experts, and others, are developing general but specific statements about the factual and conceptual content that should be presented to students by each of several different stages in the school experience.
- Some states have adopted detailed "frameworks" which specify both content and schedule in each of several disciplinary areas.
- The governors of the states are supporting development of national testing programs in various school subjects that can be used to track progress of educational improvements and which will permit comparisons among states to be made.

NSF's EDUCATIONAL PROGRAMS

4. CONGRESSMAN COUGHLIN: With the number of students of college age continuing to decline until almost the end of the century, where should our emphasis be in the development of education programs in mathematics, science and engineering? What programs is the NSF slated to support in this field in FY91?

ANSWER: Although there is no national consensus as to which of the numerous problems associated with the aforementioned decline should be accorded the highest priority, there is emerging consensus that equal attention should be given to improving the science literacy of U.S. students and to increasing the number of students who will elect to prepare themselves for careers in mathematics, engineering, and the sciences. Both of these efforts require varied activity at all levels of education, and NSF's educational programs do support projects at all educational levels. For example:

- Instructional materials development activities are supported for grades K-12 and for college;
- Faculty enhancement programs are in place for instructors in every kind of educational institution at every level--schools, two-year and four-year colleges, and universities;
- Student-related programs are in place for the middle and high school years and at the graduate level; and, both NSF and the Congress have such programs for undergraduates under consideration.

The Foundation's education programs deal with the national needs in both the short and long term and reach out to the general student population as well as to those who may become specialists.

GLOBAL CHANGE—GLOBAL WARMING

Mr. **Traxler**. I am just looking at this subcommittee's jurisdiction, you got EPA in this subcommittee, you got NASA in this subcommittee, National Science Foundation in this subcommittee.

Right now, I am looking at 75 percent of the money, and you have never been in to talk to me.

Dr. **Corell**. Seventy-seven percent.

Mr. **Traxler**. And if you count my other interests in agriculture, and assuming I have a nice relationship with Mr. Whitten, which I do, we are not doing bad here. So you and I are going to talk.

Now, there is some disagreement within the scientific community concerning whether we are seeing the initial phase of significant global warming.

On one end there is the viewpoint that Jim Hansen from NASA has the other end is anchored by somebody down in the White House.

So what do you think? Do you want to get into this tug of war?

Dr. **Corell**. One thing is obvious, that you are going to put me in the middle.

Mr. **Traxler**. I will bet you get there. What do you think? Is it too early to tell?

Dr. **Corell**. The uncertainties in our ability to predict the future is really a problem with our modeling capability. You hear all the time, I think, about the question of uncertainty in this issue of how we detect global warming.

I think we are at a stage where the signal that is coming from things that we, the citizens of this planet, are contributing to the greenhouse effect is roughly equal to natural variability.

In other words, the signal to noise ratio is such that we cannot detect one from the other. I have seen reputable scientists take the same data, and depending on the statistical techniques that they use, come up with different answers.

I think the one thing you can say is that virtually no models and no one in the scientific community, are predicting cooling with any high degree of certainty, though we were predicting that some decade or two ago.

I think the conventional wisdom is that sometime in the decades ahead, if we continue to release the greenhouse gases at the rates they are now being released, there will be warming of the planet.

And the issue is how fast and how much? That is the uncertainty question which we in the scientific community are concerned with. The CES committee has put amongst its highest priority, in fact the highest priority, the scientific question: what are the roles of clouds? That is the component in the models which has the highest degree of uncertainty.

There are models where we cannot even tell a sign, whether it's a plus or minus effect. Our modeling techniques are that primitive.

I would say that just over the last couple of years, we have seen marked increases in our capacity to handle that problem. And so long term, I am very optimistic because science is moving extremely rapidly.

Mr. **Traxler**. I am still looking for the answer to my question.

Dr. **Corell**. What I am trying to suggest——

Mr. TRAXLER. What is the current trend? Is there any trend from the information that is available at this point?

Dr. CORELL. Well, the President's economic report which this committee contributed to—largely to the section on the environment—the suggestions are that somewhere in the year 2030 to 2050, we will see either one or two degrees warmer. That is the conventional wisdom, if you integrate across the scientific community.

It ranges from virtually no warming in that time period to maybe five degrees, six degrees. That is the span. Most are somewhere in the one to two degrees.

It's come down in the last year because we have learned more and our predictions have improved to some extent.

GLOBAL WARMING

Mr. TRAXLER. When can we get more definitive in terms of those degree numbers? Are we looking at two years from now, three, four?

Dr. CORELL. I would say a decade. Part of it is what we were talking about a little while ago.

Mr. TRAXLER. What if we really move you forward?

Dr. CORELL. Pardon?

Mr. TRAXLER. What if we really move you forward, faster than you anticipate in the data collection interpretation, and making it available through the networking to the various centers or to various researchers? We have got enough—I mean, you have got incredible amounts of data that are on the shelf.

Dr. CORELL. That is correct.

Mr. TRAXLER. And what if we really make this a priority in this government of ours and establish the data centers, and we do the translating, we do the indexing, and we make it available? Now, that is probably looking at what, four years there at the earliest?

Dr. CORELL. Just to get the infrastructure put together.

Mr. BLOCH. Five, six years?

Dr. CORELL. Like I said, a decade.

Mr. TRAXLER. I am with you. Yes. Even going full speed with total commitment. All right.

OCEAN SCIENCES

Turning to ocean sciences, Page GEO-16, the legend indicates that the 1990 plan will reduce support for the academic research fleet and several research vessels will be delayed in returning to service.

Can you tell us the names of the vessels and why they have been delayed in returning to service and for how long they are being delayed, and what the impact will be?

Dr. CORELL. A couple of them have been taken out of service for retrofitting, which is being paid for by the Navy. Those have reduced our operating costs and are harmless.

The *Knorr* will come back into service this summer or late fall. It will go to work on the WOCE program, which is a high priority global change program, and will be operating in the Pacific.

The *Melville* will not return to service until 1991. There are several smaller vessels whose operating schedule are reduced. The *Cape Henalope* and the *Oceans* have light schedules.

But the overall fleet operation this year is a reasonable match with the requirements. The requirements will increase dramatically in 1991 as the major programs, WOCE the JGOFS program, to some extent the TOGA, and particularly the TOGA-COARE program, are coming up.

Mr. **Green**. We have about 20 agencies.

Dr. **Corell**. Moving back up, the global change program, particularly the oceanographic component, has been in detailed planning for a long time.

WOCE, as we call it, is the World Ocean Circulation Experiment, and it is trying to help us understand the mass movements of water in the world.

Water is a major transport mechanism for heat. It is also a major storage location for carbon dioxide and other gases. And knowing how that moves around is very important.

About eight years ago, the international community began to plan in earnest and targeted 1990 and 1991 as the start of the operational phase of the WOCE programs. We did not start it at the level that had been anticipated both because of budget requirements and frankly, just because of the planning process.

We are ready to go in that program. It has good international cooperation. It has an excellent machinery to work both with other countries and with intergovernmental bodies like the Intergovernmental Oceanographic Commission, and the World Ecological Organization.

So I think it's in excellent shape, but it does require major additional support in 1991. The required refits of the researchships science upgrade and things of that nature are preparing the research fleet to meet the science needs.

I think the fleet as we now see it, as long as we continue the retrofits, the upgrades and things that we have anticipated over the next 20 years, will be able to meet the requirements of this major program.

We do not anticipate increasing the U.S. oceanographic fleet. That is jointly recommended by the academic community and the agencies. What we do need to do is upgrade the science capabilities of the research fleet.

Did I get out what you were trying to get out?

OCEAN SCIENCES

Mr. **Traxler**. Yes, you have, and I have a follow-up question. EPA, for instance, acquired a Gulf oil rig, tender vessel, a used one, a couple years old, very cheap, sent it in for retrofit, it came out a beautiful research ship, for a couple million dollars. It is oceangoing, has a platform on the stern that is unbelievable. They used to lay pipe on it, oil rig pipe; it carried 16, 17 scientists.

I have seen some of your vessels, the *Knorr* was built in my home town a number of years ago for the Navy, of course.

The issue is should you have been looking at some other vessels that were newer, perhaps even could have been more versatile and done a better job, or are you convinced that the retrofits on your existing ships was the way to go?

Dr. **Corell**. Well, I think the answer is that we are doing most of those sorts of things. *Bernier* is a good example of an opportunity to use an oil industry vessel, with a modest conversion and upgrade of science equipment. Is now superb, state of the art oceanography research vessel for marne geology and geophysics study.

Take the *Knorr* and the *Melville;* the Nation's investment in those suggest that we ought to get 30 years of service out of them.

They are about 15 years old and it is time to do mid-life upgrades, which is what we are talking about.

The midlife refits are in the case of the *Knorr* and *Melville*, both totally redoing the power plant and at the same time upgrading their science capability.

So I think we need a mix of upgrading, and acquiring new vessels in the out years.

Mr. **Traxler**. Who pays for the outfit? Some of those ships are owned by the Navy. Do they do the outfitting, or is that your responsibility?

Dr. **Corell**. Well, in some cases if it's a brand new ship like the Agor-23 which is now under construction and will go to the University of Washington, the basic power plant and the basic capability of that vessel are included in the construction. Sometimes we and the Navy will share some of the very specialized equipment.

Mr. **Traxler**. But who is paying for that vessel?

Dr. **Corell**. The Navy.

Mr. **Traxler**. Who paid the refitting on the Knorr?

Dr. **Corell**. The Navy is paying. We are going to pay a small part of that. The primary part is paid for by the Navy.

Mr. **Traxler**. If you have got the other agencies paying for it, that is wonderful.

Let's stop—we don't need any more information.

Mr. **Bill Green**. Before we leave ocean sciences, there was a proposed regulation dealing with the requirement to have grantees be full-time faculty which has raised some concern in the ocean sciences community because in contrast to the typical faculty where people are out on summer vacation, but are otherwise teaching fulltime. I gather that in the ocean sciences community it would not be unusual for people to be away from the university and out on the ship for extended periods of time, they were concerned that they would not be eligible for grants.

Dr. **Corell**. We have not discussed that with the ocean sciences community or with the NSF Assistant Director or the Geosciences Directorate.

Mr. **Green**. I gather then technically those people would not be faculty?

Dr. **Corell**. Well, some might. Some are and some aren't. The ocean science community is a community that is heavily funded by what we would call soft money in the sense that they do depend to a larger extent on others than grant contract support.

But there is no plan at NSF to implement that kind of regulation.

NSF SUPPORT FOR FACULTY SALARY

Mr. **Bloch**. Since you bought up the subject, however, can I focus on that for a minute? The general problem is faculty salary, and how much NSF can pay towards individuals salary. And as you know, we are limited to $95,000 by Congress.

I want to focus on another aspect, however, that comes from that particular problem. Because of the $95,000 limit, we also have a restriction on people that we are bringing in from a university to be a division director, for instance, or program director or whatever it is for the Foundation. We can only pay up to that $95,000 limit, and that restricts us in the type of people that we can attract.

Now, we really would urge that that be looked at by this committee because I think the level of $95,000 is much too low today compared to what faculty pay is, especially in some of the highly skilled areas like computer science, engineering, and some of the environmental sciences.

So, since you brought it up, I thought I would speak to that.

Dr. **Corell**. There have been discussions of this matter within the Board and elsewhere within the Foundation, and that is a part of our ongoing review of how we manage the resources that are allocated.

The policy that is referenced here about denying all principal investigator salaries other than summer salaries is definitely not on the table, but we have discussed it.

ARCTIC RESEARCH

Mr. **Traxler**. Turning to GEO21, the Arctic Research program, you are requesting $16,650,000 in fiscal year 1991. This program has enjoyed some of the largest percentage increases over the past three or four years of any within the Foundation. A part of the $1 million increase will be used to initiate an Arctic Social Science program in response to recommendations by the Arctic Research Commission.

Why a separate Arctic Social Science program from the regular social sciences that are ongoing within the directorate or within the Foundation?

Mr. **Bloch**. Well, I don't think it is separate from what goes on in the rest of the Foundation—the focus is on Arctic social science, but the community that is involved in it is the social science community.

We are drawing on the same university community that the regular social science program draws on. The focus here is on one geographic area and the influence of the environment on people and vice versa.

I think you should look at it as being in line with all areas of social science activities, inasmuch as it deals with the same community out in the universities.

Mr. **Traxler**. You indicate in the legend, that this funding is in response to recommendations by the National Science Board and the National Academy of Science and also by the Congress.

How did this disparite group of people get involved in this recommendation? How did they get together on this? Where did it come from?

Dr. **Corell**. I think, as you know, the Arctic has become a central area of interest, both scientifically and geopolitically. The Arctic Act of 1984 places responsibility for interagency coordination within NSF, and the NSF Director serves as the chairman of the interagency Arctic Research Policy Committee. That body has deliberated on this subject for several years.

As we begin to look at the agenda that we need to address as a country, and as one of the eight countries that have a strong interest in the Arctic, this component of social science becomes very important.

In fact, we often talk about the health, culture and socio-economic thrust of our researchers. Our commission report on just that topic urges us to move forward, and in the 1989 appropriation report, it is explicitly mentioned this as something we should worry about and think about.

And then the Board has also, as you can recall, published a major policy document on the role of the NSF in the Arctic, and this was a component and part of that as well.

So we have looked at it from a number of dimensions.

MATHEMATICS AND PHYSICAL SCIENCES

Mr. **Traxler**. Turning to MPS-13, you are requesting $100,700,000 in the 1991 budget. On page MPS-15 under the explanation of the 1990 situation, you tell us that the subactivity was given priority in the Foundation's 1990 current plan in order to protect research and field operations.

Why was that given special priority above, say, oceanography?

Dr. **Wilson**. Within MPS, we have been concerned about basically two areas, math and astronomy, and the question of keeping the research project support as healthy as we can was a major point.

ASTRONOMY

Mr. **Traxler**. Looking at MPS-17, you indicate that upgrading projects for the Arecibo Telescope, a marvelous facility, is going to cost $22 million, and it is going to be shared between NSF and NASA.

How are you splitting that?

Dr. **Wilson**. It is about an equal amount of money. We have $5 million in the 1991 request to contribute to the change of the feed at the top of the dish. NASA is putting in $4 million to begin with to do the ground screening, and then later on NASA will put in some money to upgrade their radar facilities.

Our funds go entirely to upgrading the Gregorian feed at the top of the dish, and it is about a 50-50 split.

Mr. **Traxler**. About a 50-50 split.

Along similar lines to what Mr. Atkins was pursuing this morning, and some of this may be redundant, turning to page MPS-41, you detailed the $63 million request for major research equipment, and most of that equipment deals with astronomy projects.

You have, as you already told us, four new major projects underway. They are the replacement for the Greenbank Telescope, which as I recall is fully funded, and you won't need any more additional money for replacement there; the national high magnetic field laboratory, the Interferometer Gravitational Wave Observatory, and two new eight meter optical infrared telescopes.

Let's talk about Greenbank.

What is happening on Greenbank and will it be constructed within the dollars appropriated?

ASTRONOMY-TELESCOPE AT GREEN BANK

Mr. **Bloch**. Well, we have every intention to construct it within the dollars appropriated, and that estimate was done very carefully last year. I would say it was done in a hurry. That happens to be the truth.

Mr. **Traxler**. You didn't get too much, Erich; did you?

Mr. **Bloch**. We will take care of that problem.

Mr. **Traxler**. Gramm-Rudman already ticked you for a million. I think 75 to 74.

Mr. **Bloch**. Yeah, that is right.

Mr. **Traxler**. I hope you factored that in.

Mr. **Bloch**. Well, we will see. But let me tell you where it stands. Right now the design is being—is in progress and we are going out for bids, which will be really—will answer your question much more authoritatively than anything else sometime in the next three or four months, I guess. And out of that one we will get essentially a confirmation of what is the total dollar amount, and also the schedule on which we can rebuild that particular facility.

So, I would say right now it is on schedule. It is almost a preliminary design work that needed to be done in order to get a good bid, is being done or has been done and is being done, and we have to wait for it to come back from that bidding.

Mr. **Traxler**. What is happening, in the meantime, since the telescope was destroyed more than a year ago? Are the scientists still there? Have they been reduced? What is going on with the personnel that were involved in that observatory?

Dr. **Wilson**. The personnel has held very constant. There is a 140ft telescope that is on the site, and will continue in operation until the new dish comes in operation, estimated in 1995.

The number of personnel has been about constant.

Mr. **Traxler**. You are sort of holding onto them, I assume, until the new instrument comes in?

Dr. **Wilson**. Well, a lot of them are being used in the new Green Bank telescope, so they are not sitting there waiting for the telescope.

Mr. **Traxler**. They are very talented people; aren't they?

Dr. **Wilson**. They are and they were used for that type of activity before.

Mr. **Bloch**. The Green Bank people did more than just operate what was in Green Bank. They were also being used essentially as a design and construction shop for some of the other telescope installations, so it was really a dual function. It was not just observations and making of the Green Bank telescopes.

So that helped, obviously, you know, in that a lot of work that went on there was undisturbed by that perhaps.

ASTRONOMY: TELESCOPES

Mr. TRAXLER. Looking at MPS-45, the new Gravitational Wave Observatory will cost a total of $192 million. You indicate that these costs will be split between the United States and a consortium of the U.K., Germany, France and Italy.

Does that mean that——

Dr. WILSON. No.

Mr. BLOCH. I think you misinterpreted that. The $200 million is our share of roughly——

Mr. TRAXLER. That is the question.

Mr. BLOCH. Okay. That is toward two installations for two instruments, the total is four. The Europeans would pay fully for theirs. So the $200 million, that you have in there is our share of the two instruments.

Mr. TRAXLER. For our two instruments?

Mr. BLOCH. Right. That is different from the $8 million for telescopes where we are paying really only half of two.

So it is a little bit different.

Dr. WILSON. It may be worthwhile to point out that the two installations for the gravity wave detector is a physics experiment to determine whether gravity waves actually exist. It only becomes astronomy when you have more than two detectors. That is the contribution from the Europeans.

There is continuing interchange of technology, but no money.

Mr. TRAXLER. Help me out again. Is our total cost for our two telescopes $192 million or will it be two times that? Are we looking at close to $400 million for our two?

Dr. WILSON. Our cost is $192 for two.

Mr. TRAXLER. What do you think they will pay for their two?

Dr. WILSON. Well, it depends on the design and how they are doing it. Their design is somewhat different, and they are not as nearly as far along with the prototypes as we are. I would guess it is the same order of magnitude.

Part of the question is how big—if you have a four kilometer arm, that means money. There is a lot of civil engineering. The German design is triangular rather than 90 degree. There are a lot of uncertainties.

Mr. TRAXLER. Will ours function and provide us with the necessary data without the European component? Do we need them?

Dr. WILSON. We only need them if we are going to do astronomy.

To prove the gravity wave exists, you need two instruments to be sure that the event you see is real. You are looking for coincidences and the detectors must be spaced widely so the same truck going down the street or other spurious events does not trigger both of them.

This is an experiment to see if the physics is right.

But you can't tell where in the sky the event comes from if you just have two detectors. But if you have three or four, then you actually have a telescope, which you can tell where these events come from and make measurements on the graviton.

Mr. BLOCH. Can I enlarge on his answer a little bit.

I think we should not look at these two instances as strictly for—either way, as strictly giving an answer to a question that people have been asking now for 50, for 70 years, I guess, 80 years; namely, does a gravity wave exist. But also that it opens up a new way of doing physics and astronomy on the broad scale, just like radio telescopes opened up a new way of doing astronomy in a very fundamental way that was not, probably not even envisioned the first time.

So we should really look at that one as a new entry, and as a new way of doing physics and astronomy on the broad scale, and not just answering the question do gravity waves exist.

Obviously, if it turns out that they don't exist, then the other things will not happen. But I think there is enough evidence around that that is not that big a risk any longer as it was certainly at one time.

So I think we should look at that one as a new way of doing both of these disciplines or an additional way of doing.

ASTRONOMY: TELESCOPES

Mr. **Traxler**. We note that you are also requesting additional funding of $4 million for the engineering design studies and the purchase of glass for the first mirror of two eight-meter optical infrared telescopes.

The total request for those two instruments is $176 million or is that apiece? I am not clear. Is that total?

Mr. **Bloch**. No, that is the total for the two.

Mr. **Traxler**. And that will be split between the U.S. and its partner?

Mr. **Bloch**. And its partners.

Mr. **Traxler**. What is the largest optical telescope in terms of meters that is in use today?

Dr. **Wilson**. Oh, actually in use, other than the one in Russia, they are about four meters. But there is a sequented telescope that is under construction which is 10 meters.

There are designs for other telescopes, but eight meters is about as big as anyone is thinking of at the moment with a single piece of glass.

Mr. **Traxler**. How many meters is the telescope at Palmer?

Voice. Two hundred inch scope, so 39.37, and so that is about a four meter something.

Mr. **Traxler**. Thank you.

Mr. **Atkins**. If I could just ask one question on the gravitational wave observatory, and I don't mean to seem to be obsessed by it, but it is my understanding that the Japanese are, in a very preliminary way, while they are significantly behind us in this technology, they are looking at it and it is generating increased interest among the Japanese.

Why should we wait for this expenditure until the Japanese buy in for a piece of it?

Mr. **Traxler**. Because they will own it.

Mr. **Atkins**. That is fine with me. Fine with me.

Mr. **Traxler**. They will own it in terms of its use.

Mr. **Atkins**. The thing that I like about this is for $192 million you find out whether you get a gravitational wave, but you need to spend another $192 million to find out whether it is true or not.

Mr. **Traxler**. And then you want two others built by other countries to verify it.

Mr. **Bloch**. Well, can I comment on the Japanese aspect?

Look, that is a possibility that we could, or should involve the Japanese cooperation. I must say the Japanese are pretty far behind in terms of their experimentation from what we know, and I think we have very accurate information.

They have been working together with some European countries also over the years in refining their experiments, small developmental experiments.

So I would say that is not out of the question.

Again, I have a similar concern that the Chairman has. We want to be in a position where we are leading, and not following them, and I think that in order to do that, we have to be on the forefront of the funding.

Mr. **Traxler**. A couple of years past we had discussed new technology. Is this the "new technology telescope" that we have talked about in prior years?

Dr. **Wilson**. Well, there has been, I think, some confusion in our terminology. What we have been looking at is new technology for telescopes, and this is one result of that.

We funded the spin casting techniques of Angle in Arizona and over the years we have funded development of new detectors, etc that go on the telescope. So, we haven't been focusing on a new technology telescope as such, but new technology.

We now know how to build an eight-meter scope of lighter design, higher quality, etc.

This is the result of that previous investment.

Mr. **Traxler**. We are about to launch what is being said is the greatest optical facility; namely, the Hubble space telescope. It is a 2.3 meter instrument. It will be above the atmosphere, and give us excellent resolving power. Can you tell us what we will get from the eight-meter telescope that we won't be able to get from Hubble?

ASTRONOMY: TELESCOPES

Dr. **Wilson**. Well, a glib answer is that the Hubble telescope can't provide all the data on the new sources that it will certainly show up. Our experience in the past has been that every time a space based observatory has been put up, it puts very grave demands on the ground base facilities to back up and follow up the observations.

Mr. **Traxler**. I am looking at a publication called Vectors put out by Hughes. They had something to do with Hubble, and they are looking at the limits of a ground observatory of something in the area of two billion light years, and we are looking at the limits of Hubble as some 14 billion light years.

Now, I don't know if there are ground observatories existing. I doubt they are talking about the instrument you are proposing here.

Why should we spend that money if we have got Hubble? You have tried to answer that and I have listened carefully, but it is not coming through to me. So, say it again.

Dr. **Wilson**. Well, I think there are two answers. One that the Hubble telescope is a marvelous instrument above the atmosphere. It gives it very high resolving power because one does not have atmospheric aberration.

But it cannot do all of the observations that we need to do to understand the universe, and I don't understand that comment there about ground base as a limit of two billion light years.

Mr. **Traxler**. We were just looking at a chart that they put out.

Dr. **Wilson**. We know that we can look back longer than that.

Mr. **Traxler**. This is not a government publication, so we take it for granted.

Dr. **Wilson**. The other thing——

Mr. **Traxler**. What you are saying is there is a vast amount of information, if I understand the translation, an immense amount of information out there and Hubble, frankly, cannot get it all. Also, Hubble may be doing things out and beyond, and we may want other instruments to do things within the scope and the range of their ability, because there is so much there.

Dr. **Wilson**. That is right. We are looking at a range of frequencies throughout, from the radio telescopes, long range observations.

Mr. **Traxler**. These are both optical.

Dr. **Wilson**. I know. But then on the radio infrared, that is why these telescopes are described here as both optical and infrared. They are designed so that they are the best light gathering instruments.

And the Hubble doesn't have the aperture to get the amount of light available that we need for other purposes. There are two general purposes: high angular resolution for observing fine detail, and light gathering power for other purposes. A given telescope cannot be designed optimally for all purposes. That is why one needs a multiplicity of telescopes.

PRIORITIES

Mr. **Traxler**. Last year you received 41–42 percent of your requested increase after the Gramm-Rudman and across-the-boards were deducted. You are in for a bigger increase this year and we will make every effort, of course, to do the best we can, depending on how our 302B allocation comes out.

But if we get into a situation—here is a $64,000 question, this is number two——

Mr. **Bloch**. Making money.

Mr. **Traxler**. You didn't do bad on the first one.

This is a tough one. If we have to make the tough choices, how would you counsel us, in view of our substantial commitments to large science projects throughout the government, where could we postpone some expenditures in these large instruments that we have just been talking about? How would we rank them in a priority order if we were forced to do that? How could you help us do that?

We know they are all your children, you love them equally and you want every one of them. We know that. And you are going to tell us that, and we believe you.

But the moment of truth. You've got to make the choice. You are down here one, two, three, four. Help us out. I will tell you how good we are on this one; submit it for the record so you can think about it.

Mr. **Bloch**. Let me clarify the question.

Are you asking what is the priority between these various big expenditures? For instance, are you saying what is the priority within the whole NSF budget? Which is it? Usually——

Mr. **Traxler**. We want all the information. We need to know—we may never even get to the question.

Mr. **Bloch**. Oh, good.

Mr. **Traxler**. So, because we may not be able to do one, let alone four, we need you to tell us as among these, how you would rank them, one, two, three, four.

Mr. **Bloch**. I won't give you an answer right now, but let me—well, let me just make one comment.

Mr. **Traxler**. We hope we never have to resort to your answer. It would be one of the guideposts the committee would use.

Mr. **Bloch**. Okay. Well, that is helpful. But let me just say one thing.

I would not detract from what is already in the works, and in the works in my opinion is what we talked about before, Green Bank telescope.

Mr. **Traxler**. Yes.

Mr. **Bloch**. High magnetic field facility, which we are starting in 1990, and by the way, one reason why we put it in 1990, it had very frankly a higher priority than the SO-2 had, in our opinion, so it wouldn't disturb now.

Now, within the new ones, that is a different—I will reserve my answer to that one.

Mr. **Traxler**. All right. That is a good answer.

[The information follows:]

Priority Setting for Major Research Equipment

The NSF FY 1991 Budget Request for Mathematical and Physical Sciences includes four major research equipment projects (see page MPS-46 for a listing). These projects are:

The Greenbank Telescope, for which NSF has a separate FY 1989 appropriation of $75 million.

The National High Magnetic Field Laboratory, which NSF is starting in FY 1990 at a level of $6 million.

The Laser Interferometer Gravitational Wave Observatory (LIGO), for which NSF is requesting in FY 1991 $47 million to initiate this 4-year, $192 million physics project.

Two 8-meter optical/infrared telescopes, for which NSF is requesting in FY 1991 $4 million to initiate this 8-year, $176 million astronomy project.

With a lower than requested budget, the priority for projects for which funding has already started will be maintained.

For the two new projects, LIGO and the optical telescopes, both with extensive technical planning accomplished, the need demonstrated, deliberate postponements due to funding problems, and the strategy of sharing the costs with other international countries, it is important to begin the funding in FY 1991.

Mr. **Traxler**. While you are doing that, tell us how you would rank this. If everyone of these were to be done, it would be a very substantial increase for those major facilities. On a priority basis, would those rank above or below the increment increase for science education? You can think about that.

[The information follows:]

PRIORITY OF MAJOR RESEARCH EQUIPMENT INCREASE VERSUS SCIENCE EDUCATION INCREASE

The increase requested for the Science and Engineering Education (SEE) Activity in FY 1991 is $46.73 million over the FY 1991 Current Plan. This is 15.7 percent of the increase requested in FY 1991 ($299 million).

The increase requested for the Major Research Equipment (MRE) Subactivity of the Mathematical and Physical Sciences Activity in FY 1991 is $20.1 million over the FY 1990 Current Plan. This is 6.7 percent of the increase requested in FY 1991 ($299 million).

The two increments address different needs, but both impact the science and engineering pipeline. The highest priority within the NSF budget overall continues to be on education and human resources, where a 30 percent increase is requested. People have been our highest priority, and will continue to be so. But for several years, we have given education and human resource programs highest priority, and consequently have deferred needed facilities investments.

However, we can not forever postpone these needed investments: obsolete instrumentation or lack of instrumentation will in the end bring to a halt forefront research, just as lack of an educated workforce will do the same. The $20.1 million for facilities are not only crucial to maintain our science and engineering preeminence in the world, but will also attract bright enthusiastic young people to the world of science.

The FY 1991 NSF Budget Request was crafted very carefully, with particular attention to balance of activities, not only between research and education but also between education and human resources and research and facilities.

RESEARCH FACILITIES PROGRAM

Mr. **TRAXLER**. On RFM-1 through 3, you detailed the new $20 million Research Facility Program that was started in 1990. You are again requesting $20 million for 1991 which, as our conference report indicates, is the maximum agreed upon level of the House and Senate Committees. We noticed that on page RFM-2 they are expected to have an average duration of three years.

Now, what does that mean? Interpret that for us.

Mr. **BLOCH**. Well, the first thing I think we want to make clear is we have—we are in the middle of a solicitation right now. When the solicitation comes back and when it has appeared in classified and so forth, we hope that we will use the $40 million, $20 million in 1990, that are in the 1990 budget and the $20 million that we are asking for for 1991 together. In other words, the $40 million budget go against these solicitations that have the high priority.

And I think the three-year refers essentially that a particular construction or maintenance or improvement will take as long as three years, and but we have every intention of funding it in total out of the $40 million.

Dr. **WILSON**. It is over a three-year period.

Mr. **BLOCH**. The funds will be extended over three years, but the obligation to a particular institution will be made—it is a beginning.

Mr. **TRAXLER**. Will you——

Mr. **BLOCH**. Is that all right?

Mr. **GREEN**. My name is Richard Green.

Mr. **TRAXLER**. Do you anticipate combining the 1990 and 1991 monies?

Mr. **GREEN**. For one solicitation?

Mr. **Bloch**. We decide not to have one solicitation for approximately $20 million and then have to go out with a new one. It is not that much money compared to the requests that we are getting.

Mr. **Traxler**. How are you doing? What does it look like?

Mr. **Green**. We expect about 460 proposals.

Mr. **Traxler**. I will bet you didn't even publish anything on that.

Mr. **Green**. Proposals are due on March first, so I will have a better idea then what the numbers looks like.

As far as the total amount requested by the proposals our best estimate now is in the vicinity of $200 or $300 million.

ANTARCTIC PROGRAM

Mr. **Traxler**. Just thinking that is the first year's appropriations for the Moon/Mars proposal. Isn't that amazing?

Turning to the Antarctic program on page USAP-1. Once again, there is a fairly substantial increase of almost $25 million above the 1990 plan, or $175 million in 1991.

It is interesting that the funding for actual research in the Antarctic as a percentage of the total has declined. What do you attribute that to?

Mr. **Wilkniss**. Until the beginning of the Safety, Environment and Health initiative, we had an increase in the ratio of research dollars, especially if you combine direct funding to universities and colleges, and what we call direct science support, which is unique to the Antarctic program. We had a substantial increase in the ratio of research dollars and research support to the logistics.

This has changed now with the addition of the SEH program, but even there, a significant amount will go to research of a different kind, research monitoring.

Mr. **Traxler**. Okay. SEH means safety, environment and health. I just want to pursue this for a moment. I have two points I want to make.

In the 1991 budget, the $19 million of research represents only 10.8 percent of the total Antarctic costs. That compares to 14.3 percent in 1981. In short, we seem to be moving in the direction where the support is going to overwhelm the research very shortly.

How do we manage to get out of that? How can we reverse the trend or isn't it wise to do so?

Mr. **Wilkniss**. I think, Mr. Chairman, again, if I may say an analysis shows that the research and the support for it and the facilities we have established in accordance with reports from the National Science Board will show that we are taking care of the research. The part for which we reimburse other agencies, the logistics, supports science, and funding for science itself is on the up.

Mr. **Traxler**. Bill?

Mr. **Green**. I have had some feeling in past years that part of the reason for our continuing this program was that we pull out, the Soviets would have one there within a week. There was some feeling that the science, whether it was secondary to the national prestige issue, given the change in American-Soviet relations, that we should consider the spending constraints that they seem to be under.

Have you taken a look at the South Pole base itself and whether that can be justified?

Mr. WILKNISS. Yes, Mr. Green, the conclusion we have reached is that the South Pole is more and more becoming one of the key scientific stations on the surface of this planet, and I think your perception of the changing of geopolitics in the Antarctic is very well taken. With the changes that we see in the relationships between the U.S. and U.S.S.R., one of the driving forces to be dealt with, in the Antarctic the Russians, is disappearing. There is no question in my mind, however, that the requirements of the science, and the opportunities that the Antarctic, especially the interior, offer, will be ample justification to continue South Pole activities. Based on the President's directive to maintain an active and influential presence in the Antarctic, science for global change and all the other sciences will be pursued there. I will provide details for the record.

[The information follows:]

The Continuing Need for South Pole Station

The South Pole offers continuing challenges to mankind. First to the heroic explorers who reached the "last place on earth," then, in the modern era since the 1957/58 International Geophysical Year (IGY) and under the Antarctic Treaty, it has been a symbol of U.S. year-round commitment to use the antarctic continent for peaceful purposes and scientific exploration in mutually beneficial international collaboration. The requirements and opportunities for the next decade and the next century are magnified by the confluence of challenges in science, technology, and environmental concerns that have focused worldwide attention on the Antarctic and the South Pole as its centerpiece.

From a geopolitical point of view, South Pole Station has been pivotal in keeping U.S. options open with regard to the territorial claims of other nations on the antarctic continent. The U.S. strategy has been a most effective one, with South Pole straddling all converging claims of sovereignty. This strategy is more important than ever in the face of a doubling of Antarctic Treaty consultative (voting) parties and an ever more formidable alignment of non-claimant players. The station at the South Pole is key to the "active and influential presence" directed by the President and concurred in by the Congress. This presence is particularly important in view of serious challenges in the Antarctic Treaty System related to environmental, mineral, fishing, and tourism issues.

From an operational point of view, South Pole Station has evolved into a vital crossroads of the Antarctic continent. First, it serves to project U.S. presence at the most important location on the continent. Second, it is an acclimatization center where U.S. personnel can adapt to the high altitude regime before deploying to scientific field camps in the antarctic interior. Third, the South Pole is also the communications hub of the continent for stations and aircraft. Fourth, it is indispensable in supporting continent-wide search and rescue (SAR) missions that inevitably fall to the USAP because of our unique LC-130 capability. The demanding missions across thousands of miles of the vast ice sheet would be even more dangerous, or often impossible, without this unique center of operations.

The most interesting and most important development, however, is the emergence of South Pole station as a vital base for research projects. Continuing U.S. scientific activities at the South Pole began as part of the IGY in 1957, the year that Sputnik was launched. Since then, research efforts in space and on the ground have converged to a point where South Pole provides a unique location to study both the earth and the universe. The unique nature of the South Pole as a site for scientific investigation can be viewed as follows:

The polar regions have often been called "Earth's window to outer space." Originally, this term applied to study of the aurora and other phenomena related to the interaction of solar and terrestrial plasmas and fields. In this context, the polar upper atmosphere is a screen upon which the results of such interactions can be viewed and through which other evidence of space physics processes can be observed. Today, however, this concept of the Earth's atmosphere as a window has broadened to include important research in other fields as well. With the discovery of polar stratospheric ozone depletions, a window previously thought to be "closed" (the ultraviolet window) is now known to "open" in Spring and allows radiation potentially harmful to living systems to reach the Earth's surface. In the area of astronomy and astrophysics, the high, dry and geographically unique location of the South Pole allows scientists to use this window to examine the structure of the sun and the universe with unprecedented resolution. Research in atmospheric chemistry and dynamics, magnetosphere/ionosphere interactions, and astrophysics is among the most challenging and vital work. The geomagnetic latitude makes it an excellent site for magnetospheric cusp and cosmic ray studies. The physical fact that it is located at the axis of revolution of the Earth is in itself important, and it provides air that is almost uncontaminated by human activity and which is well mixed. To foster these fundamental and far-reaching investigations in the years ahead, the development of state-of-the-art instrumentation and new manned and unmanned facilities is necessary. The location at the South Pole will be a key element in arrays of remote sensing instruments and active experiments. South Pole is a premier seismological observatory, providing much needed coverage of the southern hemisphere.

More specifically, the geographical location means that all polar orbiting satellites pass over, or nearly over, the station on every orbit. As an example, a Low Earth Orbit (LEO) polar satellite can be tracked 16 times a day, as compared to once or twice a day at lower latitudes. For years the U.S. Geological Survey and the Defense Mapping Agency have maintained a satellite tracking station at the South Pole to monitor navigational satellites to provide orbital parameters for geodesic purposes.

The most sensitive detector on Earth for solar proton ground level events is located there. These events, which are produced by solar flares, not only provide information on how the sun works, but also affect long range communications. Within the past year, several events have been detected which will surely cause revision of the theories of solar flares and of the transport of energetic particles from the sun.

Since it is dark and clear throughout the entire winter, it is possible to optically track the diurnal changes in auroral activity for extended periods. In particular, the station is located at a geomagnetic latitude such that the magnetospheric cusp passes nearly overhead once per day near "magnetic noon," and it is therefore possible to make optical observations of the cusp signature on the atmosphere. The only other site where this is possible is Svalbard in the Arctic, which is not dark during the daytime for such long periods, nor is the weather as clear.

The atmosphere at the South Pole is extremely dry. This is ideal for observations in the infrared, submillimeter and millimeter portions of the electromagnetic spectrum, where water vapor is the principal source of opacity and noise in the atmosphere. For certain astrophysical investigations, the atmosphere at South Pole is so good that external factors such as detector noise or solar system dust become the limiting factors, rather than the atmosphere. For these studies, the site is as good as, or possibly better than, satellites.

All celestial objects describe circles about the pole. This means that they do not rise and set on a daily basis, but can be viewed for extended periods through a constant thickness of atmosphere. As an example of the importance of this, the very best measurements of the global oscillations of the sun have been made from South Pole, measurements that required nearly continual imaging of the sun for several hundred hours. This feature is also very important for measurements where a slight change in atmospheric thickness is important. An example is the present, and apparently successful, search for point sources of very high energy gamma rays from stars that uses the atmosphere itself as a detector producing secondary particles which are then detected at the surface.

Antarctica is the most unpolluted area of the Earth, and South Pole provides a site for the monitoring of atmospheric trace gases which are known not to come from local sources. Because the atmosphere is well mixed in the thousands of miles that it travels from inhabited areas, it provides a source of air that is characteristic of the global atmosphere. The wind at South Pole blows with remarkable consistency from one direction, reducing contamination problems from the station. NOAA has operated one of the four U.S. clean air facilities at South Pole since 1964. In this same vein, the discovery of the annual ozone hole has increased stratospheric research at South Pole. The station is reliably inside the depleted area, which is not true for all costal stations, and the clear sky and low water vapor content of the atmosphere make it ideal for remote sensing of the atmosphere.

In many ways, South Pole provides windows through which both outer space and the interior of Earth can be studied. Most importantly, because it is on the rotational axis, it is the only spot on Earth where long term studies can be made of the free oscillations of the Earth that are uncontaminated by rotational splitting of the oscillations. This feature is of great importance in determining the interior structure of the Earth.

NASA/NSF signed an interagency Memorandum of Agreement for joint balloon-borne research in the Antarctic which will be a key component of future research activities including at the South Pole.

South Pole Station provides an opportunity to develop a better understanding of the effect of extreme, isolated environments on human behavior and physiology, as extreme climate is combined with prolonged isolation and confinement of small groups during the austral winter. Research on what factors influence the ability of humans to remain healthy and productive under isolated and confined environments is critical to achieve successful scientific research and logistics activities in the Antarctic. In addition, research on the human experience in Antarctica is relevant to screening, training, and development of organizational and biomedical support for personnel engaged in long-term missions in space.

The present South Pole Station with its geodesic dome vividly portrays U.S. antarctic presence. Having been designed for 10 years' usable life and occupied in 1975, it has lasted well beyond expectations. However, in recent years detailed engineering surveys have pointed up severe structural problems in the dome caused by uneven structural loads from ever-increasing asymmetric snow drifts. In the 1989/90 austral summer, significant resources were expended to jack up the base of the dome to remedy severe distortions and to replace broken structural members and panels. This repair effort has alleviated immediate danger to the dome itself and to the U.S. personnel at the station. But a study leading to a "new" South Pole station has been initiated. A contract has been let to an engineering firm to assess the present situation in detail and to develop a master plan for the future. One interesting option is to further restore the dome and add satellite science stations, rather than to develop a totally new station. Challenges include snow drifting and differential movement of the ice and snow on which the station is located.

The challenge we have established for the future South Pole station "Environment One" is as follows: create and implement a design that will serve the complex frontier of science, with technologies yet to be developed, while maintaining the essential pristine character of the vast polar plateau.

In order to recognize and capture the preeminence of science at South Pole, the contractor is polling the U.S. scientific community, academia, government, and industry, to ensure that the research projects will be served well.

In addition, together with the American Institute of

Architects, we plan to have a nationwide competition of students of architecture teamed with science and engineering students to channel the imagination, innovation and concerns for the earth of the next generation of leaders into this highly visible commitment of our nation. Our intention is to construct a station at South Pole in the 1990s that will serve this country's needs well.

Mr. **Green**. Perhaps my question is a little confusing. I am not questioning the basic idea of Antarctic research. I am really just questioning that within that the South Pole base itself can be justified on a scientific level.

Mr. **Wilkniss**. I am absolutely convinced of that, sir

Mr. **Green**. One other question.

In past years, you have expressed some concern of what tourists were doing to the environment and how that was impacting on the sciences.

Does that continue to be a problem and, if so, do you have any thoughts of how to try to ameliorate it?

Mr. **Wilkniss**. Yes, sir. That is an increasing problem. The number of tourists now, I think, is substantially exceeding the number of government expeditioners. The private environmental organizations have concerns with it and have written reports and recommendations to the government on how to deal with it. Your colleagues in the Congress have introduced legislation concerning recommendations on how we should deal with tourism and regulate it.

Mr. **Green**. Thank you, Mr. Chairman.

Mr. **Traxler**. Mrs. Boggs, our resident expert on the Antarctic.

Ms. **Boggs**. I thought I had picked up that pole and stuck it in the ozone hole and got everything all cleared up, but I hadn't.

Very seriously though, I think the active participation of the National Science Foundation as the lead agency in Antarctica is a real star in the United States crown, and whatever leadership we can continue to exert there is well worth whatever we are going to have to spend on that participation.

I am very concerned because 1991 is upon us and, of course, we are going to have to do something about the Antarctic Treaty this year. I just wondered what plans were being made from the National Science Foundation point of view for that eventuality?

Mr. **Wilkniss**. Mrs. Boggs, that may also be an additional answer to the Chairman's question. We have totally concentrated on making our program competitive internationally, in the science arena and in the environmental area.

I think these will be two key issues in the Antarctic. We have built a new science laboratory that can support the forefront science that is moving on to the continent.

We have, with the committee's support, succeeded in procurement of a research vessel with icebreaking capability which, for the first time in many years, will make the Antarctic oceans, a good deal of them, accessible to us. This is a vital contribution to the global change.

And I think with the Director's and the President's initiative in the environmental area, we fill in a gap. We are setting an example of how that pristine—not totally pristine, but as pristine as it can get—how we should deal with the continent.

And I think these issues will play a major role in 1991.

Mrs. **Boggs**. Do the environmental concerns and the national concerns of the United States enter into any of your considerations about the mineral regime?

Mr. Wilkniss. They absolutely do, and the review that our Office of the General Counsel just completed shows us that we are mandated to take care of the environment, and, of course, the Antarctic Treaty is making new strides to do that. For the future, with or without the minerals regime which is being debated now, I think that monitoring and on environmental compliance program are mandatory. We are putting that in place with the resources that the committee has provided.

Mrs. Boggs. Thank you.

ANTARCTIC PROGRAMS

Mr. Bloch. I think what Peter was focusing on, is very important that we set an example. The U.S. is setting the example for not only how to do research, but how to treat—how to deal with the environment. I think we have made major progress in that particular area, since we have an agreement with OMB that we are going to spend a significant amount of dollars over the next five years on safety and health and environment. We didn't do that lightly, because we could have used the money for other things.

But I think it was very important. When we were down there we saw the effect of it, very important that we are getting into a lead role in that very important environmental area.

And, by the way, I should say that some of the noise that we have heard from private sources and people that are concerned with the environment will never vanish, but I think it has died down as they realize that the Foundation is trying to do something about it.

We can't do it overnight. That is not the point. But we are addressing this area and it will be an example for other nations.

Mrs. Boggs. Thank you, Mr. Chairman.

Mr. Traxler. You may remember that 1990 was a difficult year for the subcommittee in the overall appropriation. There were a lot of rabbits out of the hats. Some people said this was the gimmick subcommittee. Even then, we regretfully had to underfund a number of programs, including the Foundation's.

But looking at page USAP-3, you tell us that the logistic support appropriation was delayed until September 1990, per congressional direction, with serious impacts on program operations.

Isn't it fair to say, however, that that delayed obligation took place with the Foundation's concurrence and perhaps tacit approval? Certainly there was prior conversation with the agency in connection with that.

We feel terribly hurt by your statement.

Mr. Bloch. Well, you shouldn't be that sensitive.

Mrs. Boggs. They are a sassy group, Mr. Chairman.

Mr. Traxler. Yes, they are.

Mr. Bloch. Mr. Chairman, you are absolutely correct when you said that this was discussed prior to action here. This was discussed with us, and under the circumstances it wasn't our choice, I must say, but under the circumstances I know where it came from and what we had to do, and we are making every effort to live within it.

As I notified you a couple weeks ago, we have taken action to advance the Antarctic program some money from other accounts, so that the work can go on, with the understanding that we can repay the originating accounts at the time this money becomes available.

I think we will weather the storm with a couple of—with these changes that we have made. And we appreciate you bringing them up.

Mr. TRAXLER. Any way we can be of assistance?

In connection with the ice breaker, we note that you want to expend an additional $1,100,000 for another ice breaker on a temporary charter. Is that a wise thing to do in view of our constrained funding in this area?

Mr. WILKNISS. Mr. Chairman, if I may answer the question, that $1.1 million is not for an icebreaking ship. This is a recurring biannual request we make to the committee to charter a ship from the research fleet that you questioned Dr. Corell about. It assists the ice-breaking ships outside of the ice infested waters to give us a whole picture, a better picture.

Mr. TRAXLER. This isn't a new request then?

Mr. WILKNISS. No, sir. We have had that in the budget before. It appears every two years.

ANTARCTIC PROGRAMS

Mr. TRAXLER. Last year in a hearing there was a discussion of the overall evaluation of the Antarctic contractor, ITT. You indicated, Dr. Wilkniss, that the contractor had received ratings of eight on a scale of zero to ten.

You indicated that, "I can say they have turned in a more than satisfactory performance."

Given that strong recommendation, you still changed contractors in the last 12 months. You put in place a new outfit which is known as Antarctic Support Associates; is that correct?

Mr. WILKNISS. Yes, sir. I stand by what I said about the performance. However, when you go into a full fledged competition for a ten-year contract, it becomes a different ball game.

And what has happened is that the competition was won by a consortium where a company, used to O and M, operation and management, of large projects around the world teamed up with a company which is specifically geared to scientific management on a very large scale, EG&G. The team was able to write the most innovative and convincing proposal and was declared the winner.

Mr. TRAXLER. You did have some additional costs associated with changing contractors, I would assume?

Mr. WILKNISS. Yes, sir, and I cannot give you an exact figure at this time. ITT/ANS will phase out and they are in the process of giving us the phase-out costs, and I would be happy to supply them.

Mr. TRAXLER. Thank you. We would appreciate that.

The understanding is that it may have been rather substantial to do that. Do you think that is a fair statement at this point?

Mr. WILKNISS. I don't understand what you mean.

Mr. **Traxler**. That to change the contractor, that the amount of money involved will be quite substantial. Do you have any appreciation for what that is? Do you have a guess estimate?

Mr. **Wilkniss**. Yes, sir. I think it will be in the order of several million. But I think with a ten-year contract, this is not surprising.

Mr. **Traxler**. Well, we will see as the years go by.

[The information follows:]

ANTARCTIC SUPPORT CONTRACTOR SELECTION

As stated in the RFP, the prime basis for selection was evaluation of proposers technical capabilities by a technical panel. Antarctic Support Associates was the clear winner with ITT/ANS ranking a not-very-close second.

While ITT/ANS business arrangements ranked first by a narrow margin, their costs as proposed and as adjusted by NSF staff for comparability were not close. If transition costs, estimated at $800,000, and close out costs, which are expected to be less than $1,000,000, are added to ASA costs the total is still far lower than the ANS estimate.

Heavy emphasis was placed on technical capabilities because of the high degree of reliance the Antarctic Program must place on the support contractor. Because of this and because of the program and financial costs associated with transitions, the former contract was carried out by ITT/ANS for 10 years and the new one is for 6 years with two, 2-year option periods.

In summary ASA ranked a clear first among several well-qualified proposers.

Mr. **Traxler**. Turning to Page USAP-12, you indicate that you are currently supporting 800 military personnel of the Naval Support Force, Antarctic Development Squadron. How does that compare with, say, ten years ago?

Mr. **Wilkniss**. I would like to supply a correction. We are down to about 750 personnel. We had a switch of some personnel from support functions to flight functions that reduced the total number of military personnel.

In general, the level of military personnel involved has been about the same. We are in the process of looking at this with the Department of the Navy. We think that there are a number of areas where different arrangements can be made for contracting out or for consolidation of duplicating functions, on the civilian and military side where we can make further savings.

SCIENCE AND ENGINEERING EDUCATION

Mr. **Traxler**. Turning to the science engineering and education function, you are requesting $215,000,000 in 1991, which is approximately $45,000,000 increase over the current 1990 appropriation. And as we indicated earlier, that certainly is an excellent request, and it's an encouraging trend.

The increase, we note, is largely in the undergraduate and graduate areas, which the table on Page SEE-4 shows. Undergraduate Science, Engineering and Mathematics Education, would increase by 47 percent, and career development or graduate fellowships would increase by 21.7 percent. The teacher preparation enhancement, however, increases by only 10.6 percent.

We talked about this earlier. We are troubled with this allocation, with the emphasis on the college level, while we are concerned about getting the kids in the pipeline at the elementary level so that we can be assured we will have something coming out at the college level.

I am concerned that we are not addressing a need that will seriously harm us at a later point. I am going to ask you again for your thoughts on that.

Mr. **Bloch**. Well, let me start the answer, and I am sure the Assistant Director will have something to add. But let me make a couple points.

The point I made before is that we are talking about a different base for the three years.

The second thing, if you look at the graduate part of the SEE budget, you see that it has a 20 percent increase. Some of that is catch-up from previous years.

If you look at Page 22 of the book, you see that very clearly. We started to go on a pay-as-you-go basis on fellowships starting with 1989, and we are now in a catch-up mode to get back fully to the new way of funding it. And that is why you see that increase, on the right with education.

Some of it was mechanical, essentially catching up with what we told you we would do during the 1989 budget. But then I have to come back and look at the three major ones, and let's not forget that the three college areas had, as it should have, had big increases over the last three or four years.

The undergraduate area only was started really two years ago, and by the way, in terms of what the Board saw, it had a very high priority. It recommended that it had a very high priority, was in the budget and the strategy of the Foundation.

You are seeing a high percentage increase for undergraduates, but essentially in terms of dollars, it's $16,000,000 increase on the base.

I would also think that the undergraduate area is going to level off more in the future. The precollege area I have no doubt about. It will also increase. The three areas, one is not being shortchanged essentially over the years, and it's a judgment of the Foundation.

Mr. **Traxler**. I said earlier today—and I wanted you to verify or correct me, please—that the percentage of PhD. graduates in science that were foreign nationals was about 50 percent.

Mr. **Bloch**. Yes.

Mr. **Traxler**. Is that an accurate statement? I heard another statement that said about 60 to 65 percent were foreign born.

Mr. **Bloch**. I don't know about that last number, but we can submit that to you.

But let me make one point. It's highly dependent on the discipline. For instance, in engineering it was always higher than anywhere, than anywhere else. In fact, a couple three years ago in engineering it was over 50 percent that were foreign nationals pursuing degrees in the United States.

I think it's highly discipline-dependent. And we will be glad to give you a complete break-out.

SCIENCE AND ENGINEERING EDUCATION

Mr. **Traxler**. We would appreciate that. And also in terms of the total science PhD. graduates.

Now, if you could do it by discipline, that is fine. But I also need the total number.

Dr. Shakhashiri, you told us last year, "The 13 year olds who were tested last year as part of this study will be in college in another four years, those of them who don't drop out first, and will be in the work force in ten—those of them who end up well enough educated and hold a job. Looked at in these terms the lack of preparation"—here's the key to what you said,—"A lack of preparation for further education and further employment that these American teenagers demonstrated is nothing short of frightening."

So the problem at the precollege level is worse than serious. It almost seems cataclysmic. Any news since last year?

Dr. **Shakhashiri.** There is additional confirmation to the statement I made last year. On the other hand, the increased awareness across the country about the seriousness of this issue has begun to manifest itself in a number of highly visible groups and individuals as well as in the business community.

Mr. **Traxler.** I must say, I think the National Science Foundation deserves a lot of credit, especially you, Erich, for alerting the Nation to the sad state of events in American education, and most especially in science education areas, both at the elementary, secondary, and at the university level.

And I don't think, but for the kinds of information that you have put out, both to this committee and the authorizing committee, the networking that went on around this town and statements that Members have made on the Floor in support of authorizing legislation, authority of preparation bills, that people would be as aware of the problem as they are. Thank Heavens for C-Span.

We have a regular audience, get this, 22,000,000 faithful viewers. We don't sell soap. We sell something else, but not soap. Soap is cleaner.

But it's a real tribute, I think, for the work that the Foundation is doing, and I am pleased you made that point.

Dr. **Shakhashiri.** Thank you, Mr. Chairman. If I may add to that in saying that our function has not only been alert, but with the special assistance and guidance of this committee we have been able to begin some activities engaging the private sector in partnerships, leveraging the funds which we have for the summer institute programs. A whole slew of activities have begun.

And so I accept your commendation, but I want to assure you that we are only alerting the Nation about the seriousness of the problem.

Mr. **Traxler.** How many teacher institutes does the teacher enhancement segment of the budget currently support?

Dr. **Shakhashiri.** We are able to support 150 to 200 such activities in the summer institute program.

Mr. **Traxler.** Involving how many individuals?

Mr. **Shakhashiri.** Altogether, it will be close to 12,000 teachers.

Mr. **Traxler.** If you were to get this requested increase, what would happen with that number?

Dr. **Shakhashiri.** That number would go up approximately to 14 or 15,000.

Mr. **Traxler.** Should we do more than that?

Dr. **Shakhashiri.** Yes, a direct answer to your question is that we ought to do more. The question is can we do more with the present resources that we have. We are doing the best we can.

We have gotten a number of private sources, as well as other public sources, to continue the support of the activities that the NSF has initiated in this area.

Mr. **Traxler**. What would happen if your funding was doubled? Would we see twice as many teachers in the program?

SCIENCE AND ENGINEERING EDUCATION

Dr. **Shakhashiri**. See more than twice as many teachers in the program.

Mr. **Traxler**. More than twice?

Dr. **Shakhashiri**. Yes.

Mr. **Traxler**. Are the teachers going to participate in the program to that extent?

Dr. **Shakhashiri**. The requests for participation in the summer institutes program continue to be very high.

Mr. **Traxler**. Well, will they equal the number of slots that will be made available if we double that for instance, hypothetically?

Dr. **Shakhashiri**. As I said, Mr. Chairman, it will be more than double because we will be able to support teachers through the leveraged activities that we have underway. We will get other people to pay for the cost of transportation, for example.

Mr. **Traxler**. So you are saying if we were to double the money for the program, not only would you have double the slots, but you would have the bodies to fill it?

Dr. **Shakhashiri**. We would have more than enough bodies to fill the slots, yes.

Mr. **Traxler**. Last year you told us that it was a bit too early to determine if the past five years of funding of the program had begun to show some results.

What is your sense now? What do you see that might be encouraging, or is there a downward slope, or are we on a plateau?

Dr. **Shakhashiri**. We continue to be on an upward slope, Mr. Chairman. The indications from all sources are that the increased awareness we alluded to before is manifesting itself in more local and state officials taking part in a more serious way in trying to attend to the problems in science and math education.

Our informal science education programs in museums, for example, have expanded very rapidly. Our summer institutes we have already mentioned. Course materials for elementary science, high school science and mathematics activities are in demand.

We have three types of activities that we deal with, Mr. Chairman. We monitor the projects that we have, we assess the effectiveness of those projects, and then we have evaluation components in each and all of these projects.

And from all indications that we have now, we are still on an upward slope, and we are deluged by high quality proposals.

Mr. **Traxler**. It was interesting in these past few weeks that I had been back in my district, I visited a couple of plants and met with people who are in those plants. One was a heavy manufacturing facility; the other was very high tech facility that makes disks for computers. One of the three or four producers in the world for that product. They also do silicone for knee joints and other vital replacement parts.

What was interesting is, and I am trying to find out where this comes from, that in both of those situations, their scientists, their engineers and their management people were working in the community school system as volunteers, donating time to work in a classroom, teaching science on a voluntary basis in their spare time.

And secondly, those companies were bringing in, in the summer months science teachers so they could have them in their laboratories and in their business to get a few months' experience and sort of on-the-job retraining.

I think it was a very healthy thing, and I don't know if that was a Chamber of Commerce, manufacturers kind of an initiative, Department of Education, National Science Foundation, maybe all of the above.

That was a very healthy thing. Are you involved in any kinds of efforts in those lines, or is that somebody else——

Dr. **SHAKHASHIRI**. We have very vigorous involvement in those kinds of activities, and in the partnerships that we have established to form those retraining issues.

Mr. **TRAXLER**. They will adopt an inner-city school and really try to go above and beyond the situation. It's remarkable, some of the enthusiasm they have for that kind of volunteerism.

Any questions before we leave the education?

GRADUATE FELLOWSHIPS

Mr. **GREEN**. Last year, the fellowship management plan you provided had indicated that you are targeted to go up to 3,000 scholarships by 1992. Are you still——

Dr. **SHAKHASHIRI**. Yes, Mr. Green, we are. And that is the table that the director has referred to on SEE-22. It shows the details of the estimated number of fellows, and the payment schedule.

MULTIAGENCY EDUCATION INITIATIVE

Mr. **GREEN**. Just one other question in this area. Does the multiagency education initiative—where would that——

Mr. **BLOCH**. That is——

Ms. **TOYE**. It's 50-50 in Geoscience and Biological Science. I believe——

Mr. **CORELL**. It's not in SEE; it's in the research, distributed to the research directorates.

Mr. **GREEN**. If you could provide that for the record.

[The information follows:]

U.S. Global Change Education and Training Program

	Millions
Fiscal year 1991 request:	
Geosciences	$6.0
Biological, behavioral and social sciences	3.1
Total, NSF	9.1

SCIENCE EDUCATION OUTREACH IN THE COMMUNITY

Mr. **TRAXLER**. Any other question in education, if you could be brief?

Mr. **Atkins**. Just a very quick follow up. One of your grantees, the Haystack Observatory, has essentially adopted the local public school system, and their scientists have given of their own time. And I can tell you it's the single best thing that has happened in science education in that region, similar to what you said, Mr. Chairman.

I am wondering whether you have given consideration to making it a requirement of your grants that people in some way reach out to elementary and secondary education. I hope you take a look at that program because for no cost to the government, it's had a huge impact.

And I would think without any additional appropriation, you could have an enormous impact on elementary and secondary education.

Mr. **Bloch**. Mr. Atkins, thank you for mentioning that. We are well aware of it. In fact, we are in the process of opening—of asking that all the centers that we are funding that happens to be one of the centers, as you mentioned, open up their doors to exactly that kind of an activity.

Endour, for instance, has done that. Endour is out in Boulder over the last couple of years, and we want the other centers to follow suit. It's a center primarily that is very well qualified to do that because they have the personnel and the wherewithal to do it.

So we are going to make that a general kind of a requirement.

Mr. **Green**. I left some questions for the record.

[The information follows:]

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN BILL GREEN

EARTHQUAKE HAZARD REDUCTION PROGRAM

1. CONGRESSMAN GREEN: Can you tell me what the FY 91 request includes in funds for the National Earthquake Hazard Reduction Program - The answer should be $24.7M - 15M from Engineering and $9.7 from earth sciences. This is, I believe, the same amount as was allocated during FY 90, although government-wide funding for the NEHERP program has increased. Shouldn't we be putting more of our resources into earthquake research?

ANSWER: The NSF Current Plan for the earthquake activity for FY 1990 (not counting the one-time $3 million transfer pursuant to P.L. 101-130) is $23.32 million, with $14.32 million for Engineering and $9.0 million for Earthquake Sciences. The NSF FY 1991 Request is $24.75 million, with $15.25 million for Engineering and $9.5 million for Earthquake Sciences. Hence, there is an increase over FY 1990 of $1.43 million. This increase was planned but has been superceded by the additional $3.0 million that came well into the FY 1990 cycle. The programs have achieved a great deal during this period of relative government austerity.

Furthermore, we have leveraged our funds since the creation of the National Center for Earthquake Engineering Research (NCEER) in 1986. As required by the cooperative agreement which established it, NCEER has been able to match the $5.0 million annually provided by NSF with funds from New York and other sources.

NSF expects to continue to seek ways to leverage its funds in the 1990's. We anticipate that opportunities for doing this will include jointly funding projects with various states and the private sector as well as with foreign countries such as Japan. Since earthquakes are a worldwide hazard, sharing resources on an international level will be particularly promising in the 1990's, especially since it has been declared the International Decade for Natural Disaster Reduction.

NSF SUPPORT FOR RESEARCH IN SUPERCONDUCTIVITY

2. CONGRESSMAN GREEN: Last year, you provided for the record a detailed description of NSF support for superconductivity research (Pg 271). Are funds continuing to increase within the NSF?

ANSWER: NSF support for research in superconductivity has increased significantly in recent years. The FY 1991 budget request reflects an estimated increase of $22.1 million over FY 1986 levels:

FY 1986	$ 8.2 million
FY 1987	$13.8 million
FY 1988	$20.4 million
FY 1989	$26.2 million
FY 1990	$28.8 million
FY 1991	$30.3 million

Increases for superconductivity are almost entirely for high-T_C research. Support includes:

- single investigator grants ($11.9 million in FY 1990),
- research at NSF-supported Materials Research Laboratories ($4.5 million in FY 1990),
- research carried out by NSF-supported Materials Research Groups ($0.9 million in FY 1990),
- research at the Science and Technology Center at the University of Illinois at Urbana-Champaign ($4.8 million in FY 1990); and
- research and computations carried out by individual investigators and groups at several national user facilities ($5.2 million in FY 1990).

In addition to the support cited above, the new National High Magnetic Field Laboratory which will be started in FY 1990 at a level of $6 million and for which $12 million has been requested in FY 1991, will have a major impact on superconductivity research by providing a national user facility for the characterization and utilization of superconducting materials ($1.5 million in FY 1990).

The individual investigator grant mode currently supports 180 faculty, 30 post doctorals, 247 graduate students and 35 undergraduate students. The groups and center mode of support currently includes 118 faculty, 45 post doctorals, 113 graduate students, and 26 undergraduate students.

CONFLICT-OF-INTERESTS RULE

3. MR. GREEN: I noticed that HHS Secretary Dr. Louis Sullivan

dropped a controversial conflict-of-interests rule aimed at NIH-funded scientists when it became apparent that the proposal would serve to stifle creativity and virtually prevented all financial ties between researchers and private industry. Has the NSF ever proposed any similar guidelines or are any now in place?

ANSWER: No, the NSF has never proposed guidelines similar to those proposed by HHS and subsequently withdrawn. We commented negatively on the proposed NIH Guidelines. Moreover, we fund very little research that evaluates products or services. Such research poses special conflict-of-interests problems, and NIH funds a good deal of it, particularly clinical research on drugs and medical devices.

We do now have in place a much less intrusive policy, which holds that primary responsibility for regulation of potential or actual conflicts of interests rests with grantee institutions. It draws attention to basic principles that should be included in university policies by reference to two major statements of the subject adopted by university associations, both of which are reprinted in our Grants Policy Manual.

NSF is currently reexamining the whole question of investigator conflicts and whether our policy should be any different than it now is. We would not expect to adapt any policy resembling the one proposed and subsequently withdrawn by HHS.

INSPECTOR GENERAL

4. **CONGRESSMAN GREEN:** I note in the Executive Summary that the OIG has authority over scientific misconduct. Do you have the kind of technical staffing you need to engage in these types of investigations?

ANSWER: The OIG is responsible for investigating all allegations of misconduct in science, engineering and education related to NSF proposals and awards. After an initial evaluation, OIG in most instances defers to the involved institution any inquiry and any subsequent investigation. The final OIG report typically includes the institution's report as accepted by OIG and OIG recommendations based on the findings. OIG's final report then goes to the Office of the Director, NSF, for review and final action.

This question goes to the necessity of having the technical expertise of Ph.D. research scientists, engineers and educators on staff in evaluating, overseeing, and if necessary, conducting inquiries and investigations. In addition to the current small in-house technical staff, OIG can draw on the expertise of approximately 400 staff Ph.D. scientists, engineers and educators employed by NSF. Additional expertise is obtained by the use of consultants. Technical expertise is fundamental to our work in this area and is an integral and dominant part of a team effort that involves legal and investigative expertise.

At present, the number of technical staff members in OIG is inadequate. However, we soon expect to obtain one additional Ph.D. research scientist/engineer and a full-time secretary for OIG's Office of Oversight which has responsibility for handling allegations of misconduct. This should help alleviate our current shortage.

5. CONGRESSMAN GREEN: I see that you plan to do your auditing in-house. How is this working? I can tell you that I see some significant advantages to this method - it can save time & expense, it certainly minimizes the ability of grantees to "slip things through the cracks" and I guess it saves grantees money.

ANSWER: The OIG began its detailed planning and identification of auditees for this activity during the current semiannual period (October 1989 to March 1990). The actual audits began in January 1990.

To date, four audits have been completed with the expectation that two more will be finished by the end of March. For the four completed audits, the savings and benefits realized by doing the audits ourselves are as follows:

Our cost was two-thirds of the estimated cost of having an Independent Public Accountant (IPA) do the work for us under contract. In addition, NSF and the OIG did not incur the cost of preparing and processing the documentation required for the issuance of the contract/task order for the Independent Public Accountant.

The audits were completed with the reports reviewed and issued within a two to three month period. The Independent Public Accountants' required on average, from request for proposal to issued report, a full year.

The findings and questioned costs in the OIG produced audits have been approximately equal to the IPA reviews for the obvious compliance and questioned cost items. In addition, we have been able to provide immediate help, had findings which had their origins and solutions at NSF, and have produced types of findings that had not previously been reported.

There will be a residual benefit for reports requiring audit advice for final resolution. The auditor who made the finding and the workpapers supporting the report will be in NSF.

Although the OIG audits will not relieve the grantees from prudent management and oversight of their own programs, annual audits and audits in conformance with the grant conditions and OMB Circulars, they will provide a reference for the grantees to use in the requirements of NSF. The on-site review by OIG staff will also provide a contact for the grantees when questions arise.

6. CONGRESSMAN GREEN: However, it does trouble me that I see open audit findings going as far back as January 30, 1985, now over 5 years ago. (pg. 16-17).

What's the story with this? Have some of these been resolved since the report was issued?

ANSWER: The Semiannual Report to Congress by NSF's Office of Inspector General identified thirty-one audits which had outstanding management decisions as of the beginning of NSF's initial reporting period. Of these thirty-one, fourteen might be characterized as unusually old; that is the reports were issued prior to calendar year 1988. Since the issuance of the semiannual report, six of the fourteen audits have been satisfactorily resolved and are now considered closed.

Of the remaining eight, three have had NSF management decisions made; which means we have made our determination as to the amount of funds due NSF and have initiated steps to recover the funds. Included in these three is the oldest unresolved audit, involving the University of Nebraska. Of the other five, either we have requested additional information from the audited organization or we are in the process of evaluating information from the audited organization and negotiating a settlement.

Mr. Traxler. Thank you.

We have got two minutes to catch this vote. We should be back within 10 minutes, and we will conclude very promptly.

[Recess]

NON-U.S. CITIZEN DOCTORATES

Mr. Traxler. We have just got a few administrative questions. The committee will be in order, and we will recognize Mr. Bloch.

Mr. Bloch. I wanted to go back to the question you asked on non U.S. citizens doctorates, and I would like to produce for the record an appendix table 2-13 of the new Science and Engineering Indicator, 1989, which lists by field a total, gives the total of doctorates, as well as temporary visa one and permanent visa one.

In total, it's about 30 percent that is non U.S. citizen, in total, within two fields, mathematics and engineering. It's about 50 percent, and then it varies with various others.

If we have any additional information, that also throws—this doesn't throw any light on your question of foreign born. It doesn't have it. It's only visa, essentially.

If we have any addition information, we will supply it.

[The information follows:]

Appendix table 2-13. S/E doctorates of non-U.S. citizens, by visa type: 1978-88

Field	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total, all fields	17,948	17,245	17,199	17,833	17,830	17,976	18,107	18,323	18,898	19,312	20,257
Non-U.S. citizens, permanent visas	970	927	935	876	834	877	917	889	969	1,064	1,086
Non-U.S. citizens, temporary visas	2,506	2,686	2,843	2,882	3,051	3,328	3,606	3,960	4,086	4,364	4,838
Total science	14,625	14,765	14,729	15,105	14,984	15,195	15,194	15,157	15,483	15,600	16,067
Non-U.S. citizens, permanent visas	645	605	636	575	538	558	543	584	606	709	729
Non-U.S. citizens, temporary visas	1,738	1,791	1,792	1,990	2,021	2,158	2,340	2,541	2,684	2,832	3,115
Physical sciences	2,611	2,574	2,521	2,627	2,694	2,802	2,845	2,916	3,080	3,212	3,320
Non-U.S. citizens, permanent visas	183	155	151	147	119	128	119	136	133	147	137
Non-U.S. citizens, temporary visas	387	415	426	442	506	530	584	620	758	798	862
Mathematics	838	769	744	726	720	701	698	686	729	740	749
Non-U.S. citizens, permanent visas	47	51	62	43	41	46	38	42	38	51	43
Non-U.S. citizens, temporary visas	155	149	139	186	182	209	232	228	272	302	304
Computer science	121	210	218	232	220	285	295	310	399	450	514
Non-U.S. citizens, permanent visas	5	12	13	20	12	27	17	24	47	32	42
Non-U.S. citizens, temporary visas	26	32	43	40	59	72	69	89	123	143	174
Environmental sciences	623	646	628	683	657	637	614	617	669	628	726
Non-U.S. citizens, permanent visas	22	34	26	16	29	30	25	32	24	25	30
Non-U.S. citizens, temporary visas	68	71	80	85	81	106	105	119	166	125	137
Life sciences	4,369	4,501	4,715	4,786	4,844	4,756	4,877	4,902	4,806	4,813	5,121
Non-U.S. citizens, permanent visas	165	161	186	159	140	150	149	151	165	206	262
Non-U.S. citizens, temporary visas	559	562	562	613	603	629	675	779	711	780	898
Psychology	3,055	3,081	3,086	3,358	3,188	3,347	3,257	3,117	3,124	3,177	3,058
Non-U.S. citizens, permanent visas	54	45	50	47	47	64	51	50	65	59	56
Non-U.S. citizens, temporary visas	61	73	71	80	65	79	88	81	81	85	84
Social sciences	3,008	2,864	2,786	2,791	2,680	2,696	2,658	2,607	2,746	2,580	2,579
Non-U.S. citizens, permanent visas	149	137	148	143	150	121	146	141	158	187	156
Non-U.S. citizens, temporary visas	472	489	441	504	515	524	566	615	633	596	656
Total engineering	2,423	2,480	2,479	2,528	2,646	2,781	2,913	3,166	3,376	3,712	4,190
Non-U.S. citizens, permanent visas	325	322	298	301	296	319	274	315	343	355	366
Non-U.S. citizens, temporary visas	768	815	851	942	1,030	1,170	1,269	1,418	1,372	1,532	1,723

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-8.

Science & Engineering Indicators—1989

Mr. **Traxler**. Of those visa PhD. candidates, is the general rule that their government or some entity other than themselves pays for their advanced education? Is there a general rule here?

Mr. **Bloch**. I think it's different from case to case, and certainly different from country to country.

For instance, China had, as a strategy, they paid as the first year of PhD. students and after that the students were on their own. And many of them were supported obviously by teaching or by doing work in laboratories or what have you.

So I don't think there is a general rule. But we have information of how people are supported, foreign students are supported, and we can make that available to you, also.

[The information follows:]

Support for Students From the People's Republic of China [PRC]

In FY 1989, the Foundation awarded a total of 144 individual awards and obligated nearly $1.3 million for supplemental support of individuals from the People's Republic of China on NSF awards.

NSF ADMINISTRATIVE EXPENSES: PD&M

Mr. **Traxler**. Thank you. We will insert in the record at this point the administrative expense tables, and we note that all the administrative expenses through the Foundation through fiscal 1989 were included in a single activity, and that was PD&M.

[The information follows:]

TOTAL ADMINISTRATIVE EXPENSES OF THE FOUNDATION

	1989 actual	1990 estimate	1991 request	Difference
Program development and management [PDM]	91,300,000	96,383,000	102,500,000	+6,117,000
Office of Inspector General [OIC]		2,560,000	3,000,000	+440,000
Headquarters relocation			5,500,000	+5,500,000
Total	91,300,000	98,943,000	111,000,000	+12,057,000
FTE:				
PDM	1,171	1,195	1,225	+30
OIG		25	27	+2
Total	1,171	1,220	1,252	+32

A separate appropriation for the Office of the Inspector General was created in fiscal year 1990. In fiscal 1991, the Foundation proposed a separate activity for costs related to the relocation of its headquarters, the total administrative request is about $111,000,000, an increase of $12,057,000 of comparable funding level.

Staffing for the Foundation would increase from 1171 FTE in 1989 to 1220 FTE in 1990, 1252 FTE requested for 1991.

For years, the appropriating paragraphs for research related activities and science education activities have carried provisos that when the amount appropriated is less than the total amount authorized, all programs will be reduced proportionately.

You are asking that those provisions be deleted for 1991. Why?

Ms. **Toye**. This is the boiler plate language that goes with each appropriation, and I think what you see there is a predisposition that we have to suggest only the deletion of any language that tends to confine or circumscribe us.

I think in fact we followed that general guidance and this committee has been most reasonable in dealing with reprogramming requests. But as a matter of principle, we try to——

Mr. **Traxler.** The Foundation is requesting $69,000,000 in personnel compensation and benefit funds to support 1225 FTE under the 1991 PDM activity. That is an increase of $4,400,000 or 6.8 percent and 30 FTE above the 1990 level.

On Page PDM-5 of the justification, there is an indication that this includes the cost of SES pay raise scheduled to become effective in 1991. The question is, does the $69,000,000 requested in 1991 for personnel compensation benefits include the anticipated January 1991 pay increase of 3.5 percent?

Ms. **Toye.** No. The 1991—the annualization of the 1990 is, the 1991 is not.

Mr. **Traxler.** Shouldn't the 1991 request include such costs?

Ms. **Toye.** Speaking as the Controller, I wish that we could all get away from the methodology that sometimes goes into some of these requests, but we have typically not been allowed to ask for funding for pay raises that were not yet enacted.

The SES is a bit different because it stems fundamentally from the executive order. Mr. Thompson has told me that his understanding with OMB was that agencies were, in fact, encouraged to do this.

I commend him for having a better contact with OMB than we have, which was the confusing budget area, and we simply do not have clear guidance.

Mr. **Traxler.** Let me just say that we have come on this by a letter to Chairman of the full committee, Mr. Whitten, dated January 29, 1990, much later than your budget, of course, and the information was unavailable at the time that your budget was submitted, signed by the Director of OMB, which says federal pay raise estimates for assumed pay raises for 1991 and beyond are included in effective accounts rather than in an undistributed allowance as in the past.

Distribution of policy estimates were paid to the account level as is consistent with the treatment of pay under GRH baseline estimating rules. So they will let you know next year.

Since the costs of January 1991 pay raise aren't included in the $69,000,000, how much additional funding will you need for that 3.5 percent estimated pay raise.

Ms. **Toye.** It would be roughly $2,000,000.

Mr. **Traxler.** On page PDM-3, the justification indicates that the number of FTEs for staff offices of the Director in 1990 is to increase from 159 to 168. Why should the number of FTEs in the staff offices of the Director increase in 1990 above the level requested last year when the total FTEs in 1990 was less than the request?

Ms. **Toye.** There are two effects that created most of this. One is we recently rejoined the Presidential Management Intern program after an absence of some years. For convenience we charged those young people to the director's office.

The other effect was Mr. Green and the Research Facilities Modernization Activity, which we have launched in the Offices of the

Director during its start-up phase, and those two together account for that difference.

Mr. **Traxler**. Total staffing for the Foundation, including the OIG, goes from 1,171 in 1989 to 1,220 in 1990, 1,252 in 1991. Do you anticipate that additional staffing will be requested in fiscal 1992?

Ms. **Toye**. Yes. Our plans are for increases at the rate of about 25 to 30 a year during 14 percemt programmatic increments that we are asking for.

Mr. **Traxler**. What was the percentage of programmatic increase that you just mentioned?

Ms. **Toye**. It's about 14 percent on average, and the personnel plan that is linked with that is about an increment of 30 FTE per year that are associated with those growing programs.

Mr. **Traxler**. NSF is requesting $3,600,000 for travel in fiscal year 1991, an increase of $700,000 or 24 percent above the current amount obligated in 1989.

How much of the increase is due to increased cost of travel, how much due to an increase in the number of trips?

PD&M

Ms. **Toye**. Some of each. More I would say the increased cost of trips. We have the same difficulty as an institution that one has privately these days with the cost of travel because it's extremely sensitive to the day that you happen to call the airline to get your tickets.

We have not seen a big change in per trip cost in the last two years, so we have built in very modest expectations along those lines, a little bit, but not much.

Mostly, we are looking at more trips.

Mr. **Traxler**. In the table on PDM-7 under rents and communications, it's noted that office space rentals in 1989 total $7,634,852. Last year you estimated 1989 office space rentals to be $7,840,000. Why did your 1989 office space rentals cost approximately $200,000 less than estimated in prior years?

Ms. **Toye**. We intended to expand our holdings very slightly during that year, and we found difficulty in finding space at a cost we could absorb. And Mr. Bloch's preferences are not to go in that direction anyway, so we simply stayed with what we had.

Mr. **Traxler**. We are not criticizing you for not spending the money; okay?

Ms. **Toye**. But that was the rationale. We are going to expand a bit on L Street.

NSF RELOCATION

Mr. **Traxler**. Congratulations. You came in a hundred thousand dollars below last year's estimate on the usual telephone, telegram, postage, et cetera, very frugal over there. Penny pinchers.

You are looking for $5,500,000 for headquarters relocation costs in 1991. You indicate this activity is temporary and ought not to extend beyond fiscal year 1994.

On page NHR-3, the justification indicates that the total cost for relocations through 1992 was $17,000,000. That means the 1992 request will be for $11,500,000. Does that sound right?

Ms. Toye. May I defer to Mr. Fenstermacher?

Mr. Traxler. Sure; 1992, $11,500,000.

Mr. Fenstermacher. Yes, sir. $11,500,000.

Mr. Traxler. And what do you estimate the relocation costs in 1992 and 1994 to be, if any?

Mr. Fenstermacher. Well, very little if our schedule holds. We referenced 1993 and 1994 just in case—the construction schedule we have now is a pretty optimistic one. Things really have to go very well, with construction of the base building beginning by this September so that we can have occupancy by September of 1992.

We are saying costs may stretch out over 1993 and 1994 just in case the building construction schedule slips, in which case we may slip some of that eleven and a half million from 1992 to 1993 or 1994.

Mr. Traxler. Was anything oblogated in 1989 for relocation costs, and if so, how much?

Mr. Fenstermacher. We had some contract costs in terms of planning.

Ms. Toye. My recollection is that the bulk of that was in 1988, and I believe it was about a quarter of a million. There may have been some small increments in 1989, but we simply treat it in our administrative support contracts.

Mr. Traxler. What will be obligated in 1990 for relocation?

Ms. Toye. In 1990 for relocation.

Mr. Traxler. Anything?

Mr. Fenstermacher. Possibly $50,000 worth of planning contracts.

Mr. Traxler. You are going to be in the new building in 1992; is that correct?

Mr. Fenstermacher. We hope to be. That is the plan now. September of 1992.

Mr. Traxler. What size of a building are you looking for? How many staff will the building be able to accommodate?

Mr. Fenstermacher. Probably up to 1700, 1650 work stations.

Mr. Traxler. And how did you arrive at $17,000,000 for relocation cost for 1992?

Mr. Fenstermacher. That was one of the things that we did through our architectural and engineering contractors. They helped us come up with the estimates. We have also been dealing with NASA and some other federal agencies, the FCC, ITC, that have relocated in the last few years or are in the process of relocating now.

TWO-YEAR APPROPRIATIONS

Mr. Traxler. You are requesting some $3,000,000 for the Office of the Inspector General for the year 1991, an increase of $404,000 above 1990. And, you are requesting a two-year availability of funds for that account, although your program and financing schedule shows no anticipated unobligated balance at the end of the year and, of course, most of the salaries and expense accounts are annual.

Why do you want a two-year availability?

Ms. **Toye**. Do you want to speak to that, or is that fundamentally a technology question?

Ms. **Sundro**. I will defer to you on that one.

Mr. **Traxler**. She never gets a chance to say anything. This is your moment.

Ms. **Sundro**. I think Mr. Bloch might dispute that.

Mr. **Traxler**. Well, we understand that, too.

Ms. **Toye**. I think all of our accounts, as you know, are two-year or no year. Our RR&A is a two-year account, and science and education is a two-year account, although by agreement with you, we do not carry over in the other area.

The two-year provisions is very useful for handling contracts, that sort of thing, and I think we simply felt it should be extended. It's a very useful tool.

SUMMARY

Mr. **Traxler**. Is there anything else we should know?

Mr. **Bloch**. Yes, but I would like to say a couple things. first of all, we appreciate you spending today looking at our programs, and I just wanted to say a couple things that came out of the discussion.

The world is changing rapidly on all of us, and it's moving from a military confrontation to an economic one. And I just wanted to say in that kind of an environment, the focus that we have and the the Foundation has on research as well as on education, both will be extremely important to determine how well this country's position in this increasing economic competitive kind of an environment.

We have talked at length about research; we have talked at length about education. I hope that your 302B allocation will cover both research and education, and if there is something left over, I hope that you will seek education.

But really on the lines of that you have to look and we have to look at the total pipeline from precollege all the way through to undergraduate education, and the undergraduate part as well as the precollege part has very important roles to play in the future of the country.

So while you might not like our allocation of funds, they were done not without foresight, and I hope that you see that in your power first of all, and also that you agree with us, that what we are asking for is rational and reasonable; and we hope that you will consider our request.

And thank you for today.

Mr. **Traxler**. Erich, those are well stated words, and certainly the world of this decade and absolutely the next century is going to be total economics, and I think of it as kind of economic warfare. And I think our Nation is totally ill-equipped for that kind of a conflict.

Unfortunately, there aren't too many people who recognize this and are prepared to make the shifts in the priority of federal spending. And I am appreciative of your words.

I would say to you that these questions that we have asked over the course of today's hearing are very helpful to us because they provide us with information. It is difficult, I know, for agency personnel to preach that we are spread kind of thin, and there are many demands made upon you.

I have constituents back home who always have first call on my time. We have other responsibilities here in the Congress. There are other agencies within the subcommittee, and I am beginning to suffer from Alzheimer's, and these sessions are very helpful. We are very grateful.

You are a very fine credit to the agency, but more importantly to our government, and our Nation. I am very proud to be associated with you.

Mr. **Bloch**. Thank you very much.

Mr. **Traxler**. Thank you all, ladies and gentlemen.

[Questions for the record and the justification follow:]

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSWOMAN LINDY BOGGS

EPSCoR AND 1992 PLANS

1. CONGRESSWOMAN BOGGS: I understand that all 16 EPSCoR States and Puerto Rico will recompete for funding in 1992. Can you tell us about the guidelines for that competition?

ANSWER: The National Science Foundation (NSF) plans to conduct an EPSCoR Advanced Development Competition in which all 16 EPSCoR States and Puerto Rico will compete for continuation awards. The guidelines for this competition will be transmitted to the EPSCoR States by early April, 1990. EPSCoR Advanced Development proposals will be due at the Foundation in January 1991. We expect to announce awards under this competition in December 1991.

2. CONGRESSWOMAN BOGGS: Will there be a funding lapse between the end of the current program and the new one?

ANSWER: In nine EPSCoR States the current awards will terminate in the Spring, 1992; in the remaining eight States the current awards terminate in mid-October 1991, 2 months prior to the start of an EPSCoR Advanced Development award. Given the EPSCoR goal of mainstreaming investigators and establishing State structures for continuing EPSCoR goals, we do not view this 2-month hiatus in funding as a problem.

3. CONGRESSWOMAN BOGGS: What is the role envisioned for individual investigators in the 1992 competition?

ANSWER: The specific role of individual investigators in EPSCoR projects will be determined by the States themselves. The EPSCoR Advanced Development program places emphasis upon developing a critical mass of scientists and engineers grouped in research clusters, with a minimum of three investigators per cluster. States may also focus on the development of a single major science and technology or engineering research center. In some States the need to develop isolated individual investigators, not connected with a given research cluster, through "starter" or "seed-type" grants may be an important and integral part of the State's overall EPSCoR effort. For these grants, we strongly recommend States to include these activities as part of their overall infrastructure plan and support them with State matching dollars.

4. CONGRESSWOMAN BOGGS: What is the projected overall funding level that you expect to request, and how many of the 17 States will be funded in that competition?

ANSWER: The EPSCoR budget request for FY 1991 is $10 million. The long-range planning estimate for the FY 1992 EPSCoR Advanced Development competition is $15 million. With an annual EPSCoR award of about $1.5 million per State, it is anticipated that approximately 10 Advanced Development awards could be made at the $15 million level.

5. CONGRESSWOMAN BOGGS: I understand that the competition may include both an infrastructure component and a research component. Has any thought been given to funding these as separate and successive competitions?

ANSWER: A great deal of thought has been given to the relationship between general infrastructure improvement within a State and the research enhancement components selected for development under EPSCoR. Consistent with EPSCoR tradition and experiences, the 1992 competition will not treat these as separate entities. These two activities are highly inter-related and symbiotic in nature. The guidelines do allow for funding of an exceptionally meritorious Infrastructure Improvement Plan without funding of the research enhancement section of the overall proposal. EPSCoR will not fund research enhancement components unless it is accompanied by a strong State commitment to enhance the S&E environment in the State.

6. CONGRESSWOMAN BOGGS: In having only one competition, will States funded in more recent rounds be placed at any disadvantage? In other words, will States funded more recently have adequate time to develop the same level of infrastructure as States funded in earlier rounds?

ANSWER: We do not believe newer entrants into EPSCoR will be disadvantaged. The 1992 competition is based on 10 years of experience in the program designed to provide flexibility to States in developing their EPSCoR Advanced Development plan. Recent entrants into the program may focus more on the infrastructure component. Review criteria take into consideration not only progress to date but also potential for future improvement. All States have the opportunity to build on past EPSCoR improvements or to initiate new areas of interest without penalty.

ROLE OF EPSCoR COMMITTEES AND THEIR STATES

7. CONGRESSWOMAN BOGGS: The FY 1991 Budget requests almost $47 million in increased funding for the Science and Education Activity and $106 million in increased funding overall for education and human resource development. Now that we have strong EPSCoR committees operating in the EPSCoR States, it is important that they continue to play a role in education, as well as research. In effect, they could serve as a focal point for

education initiatives within their States. In light of your emphasis on science education, how do you think these committees could best serve their States?

ANSWER: The EPSCoR committees serve as important potential contacts for other Federal agencies (e.g., NASA) interested in initiating EPSCoR-type activities. In addition, we have encouraged the personnel from EPSCoR States to submit proposals to the Science & Engineering Education (SEE) directorate of NSF and have provided liaison between the SEE directorate and interested parties.

We agree that the EPSCOR state-wide committees have made a contribution to the scientific and engineering activities in the States. We have encouraged the committees to address education and human resources initiatives in their state.

The development of strong science and mathematics programs nation-wide is a major concern to NSF. The SEE directorate has proposed a new States Initiatives program to effect systemic changes in the quality of the science and mathematics programs in the States. We would be pleased to convene a meeting with representatives of the EPSCOR state committees in the Summer to describe the States Initiative, to encourage participation in this and other SEE programs, and to discuss ways in which the EPSCoR committees could assist in developing stronger education and human resources initiatives in their states.

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN ALAN MOLLOHAN

UNDERGRADUATE EDUCATION

1. CONGRESSMAN MOLLOHAN: What do you see as the most serious problems at the undergraduate level? What is NSF doing to address them?

ANSWER: The most serious problems are:

a) a decrease in the proportion of freshmen interested in undergraduate science majors;

b) the loss of nearly 50 percent of academically able science and engineering majors during matriculation at the lower division (freshman and sophomore years) of the degree programs;

c) a paucity of minorities persisting as undergraduate science and engineering majors; and

d) the lack of process-oriented contemporary science, mathematics and engineering course and curricula.

Specific NSF programs designed to address these problems are:

- Instrumentation and Laboratory improvement; providing much needed instructional instrumentation and laboratory revitalization.

- Science and engineering faculty development; providing release time for undergraduate faculty to reinvigorate their careers and keep up to date with recent advancements in science and engineering.

- Materials, Curricula, and Technologies; providing wholesale large curriculum renovation as well as small-scale point-specific alteration of curriculum.

- Career Access and Alliances for Minority Participation; providing programs to help minority and women students get into and stay in science and engineering undergraduate programs and aiding their matriculation into graduate school.

- Research for Undergraduate Students; providing research experiences in real-life laboratories and opening up mentoring relationships.

- Planning and Evaluation to assess the effectiveness of these programs.

DISTINCTION BETWEEN RESEARCH AND EDUCATION

2. CONGRESSMAN MOLLOHAN: Referring to page 10 of the Research and Related Activities summary section (R&RA-10), the section entitled Undergraduate Research and Education: What is the distinction between research and education here? How much of this effort is for research and how much for education? How does this balance agree with recommendations made by outside studies such as the National Science Board report on Undergraduate Education?

ANSWER: Education programs at NSF take place not only in SEE Activity but also in the research Activities. The Foundation believes that education and research priorties and needs are closely linked, and that the most effective educational activities will reflect the particular needs of specific disciplines.

The primary research components are Research Experiences for Undergraduates ($14.6 million), Research in Undergraduate Institutions ($14.5 million), and Research Opportunity Awards ($1.5 million), all of which are funded exclusively from the R&RA account.

The primary education components are Faculty Enhancement ($4.0 million), which is funded from the SEE account, Course and Curriculum Development ($27.5 million from the R&RA account and $8.0 million from the SEE account), and Instrumentation and Laboratory Improvement ($3.3 million from R&RA, $23.0 million from SEE).

The balance of programs which comprise NSF's FY 1991 undergraduate activities are designed to attract women and minorities to careers in science and engineering. These programs include Career Access Centers ($15.0 million in SEE and $0.6 million in R&RA), Alliances for Minority Participation ($10.0 million in R&RA), Research Careers for Minority Scholars ($9.3 million in R&RA), and a targeted program in the Geosciences Activity ($1.3 million in R&RA).

This balance reflects a faster shift toward attraction and retention programs over that envisioned by the 1986 National Science Board report on Undergraduate Education. It also reflects a significant expansion of undergraduate course and curriculum revitalization aimed not only at generic introductory level courses but higher level courses where students begin to choose various science and engineering fields as permanent interest.

FACULTY INCREASE

3. CONGRESSMAN MOLLOHAN: I note from the table on the same page

(R&RA-10) that there is very little increase for faculty. Does this indicate that science faculty as a whole are up-to-date in their fields? How about faculty at 2-year and 4-year colleges?

ANSWER: The Faculty Enhancement Program is receiving a 38% increase from $2.9 to $4.0 million in FY 1991. This program focuses on conferences, workshops and short courses aimed at assuring that faculty are up to date in their fields. The program emphasizes the strengthening of faculty at 2- and 4-year colleges.

LEVEL OF FUNDING FOR UNDERGRADUATE EDUCATION

4. CONGRESSMAN MOLLOHAN: Many of our constituents, especially those in 2-year and 4-year colleges, express concern about placing the majority of the funds for undergraduate education in the research programs. Can you tell me what fraction of the 1989 undergraduate education funds in R&RA went to 2-year colleges? to 4-year colleges? and to research universities? Please give me the same information for the undergraduate funds that were in Science and Engineering Education (SEE). How does this compare with the distribution of our U.S. students in these types of institutions?

ANSWER: Less than one percent of the FY 1989 undergraduate funds in R&RA went to 2-year colleges, compared with about 5 percent in SEE. In four-year colleges, the ratios are six percent in R&RA and 11 percent in SEE; in master's degree granting-institutions, 19 percent in R&RA and 33 percent in SEE; in PhD. degree-granting institutions, 68 percent in R&RA and 39 percent in SEE; and other institutions (such as non-profit institutions), 7.5 percent of R&RA and 12 percent of SEE undergraduate funds.

In terms of enrollment, there were approximately 4.5 million students enrolled in two-year institutions, 3.9 million in four-year and masters degree-granting institutions, 3.4 million in Phd. degree-granting institutions, and 467 thousand students in specialized institutions.

5. CONGRESSMAN MOLLOHAN: It is somewhat confusing that this general section on undergraduate science education funding is located in the R&RA chapter rather than the SEE chapter. Why is that?

ANSWER: Placement here is as much a philosophical as it is a practical matter. Philosophically, education and research are not separate activities, but are inherently and profoundly linked. For our system of undergraduate education to perform as it should, that linkage must be strengthened, and the attention and energy of the entire scientific community must be harnessed. From the outset, we have been determined that the undergraduate initiative must be fully integrated into the mainstream operation of every part of the agency.

As a practical matter, six of the seven contributors and a substantial portion of funding ($84 million of the total $134 million) are located in the R&RA account. While the undergraduate programs funded out of the SEE account are also significant, they are, as you note, described in detail in the SEE justification.

BUDGET WRITE-UPS FOR R&RA AND SEE

6. CONGRESSMAN MOLLOHAN: Referring to pages 15-18 of the SEE chapter now, we see a section for undergraduate education with specific program lines, for example: Instrumentation and Laboratory Improvement, Faculty Enhancement, etc., with funding history and FY 1990 and 1991 requests. I can't locate such information in the R&RA chapters. For instance, if we look at the table on page 1 of the Biological, Behavioral, and Social Sciences, (BBS-1), and other such tables, no specific information about undergraduate education appears. Why aren't undergraduate science education activities in R&RA accounts described as explicitly as they are in SEE? I'd like to see a detailed history of undergraduate expenditures in the R&RA accounts parallel to the SEE tables. For instance, last year's budget request (see 1990 Distributed Programs, pages 2-3) shows a plan to spend in 1990 $29.5 million in Instrumentation and Laboratory Improvement, $16 million in SEE and $13.5 million in R&RA. What is the current 1990 plan for this program?

ANSWER: The budget display of both the SEE and the R&RA account is presented to the program level. Since the primary focus of the SEE Activity is education, SEE programs are organized around discrete education activities. Funding modes for undergraduate education in the R&RA account focus on the research experience (see earlier response above) and are imbedded within the research programs. Thus, types of programs that exist in the R&RA account (such as REU, RCMS, RUI and ROA) do not exist in the SEE account, and vice versa.

The program you cite, Instrumentation and Laboratory Improvement (ILI), however, currently does exist in both accounts. The FY 1990 Current Plan for it totals $22.3 million, $15.8 million in SEE and $6.5 million in R&RA. In FY 1991, program responsibility for the entire ILI effort is being moved, unencumbered, to the SEE account, providing SEE with responsibility for the full range of undergraduate instructional instrumentation programs.

CURRICULUM DEVELOPMENT IN R&RA vs SEE

7. CONGRESSMAN MOLLOHAN: Referring again to the 1990 budget request, I note that the undergraduate division of SEE was assigned the leadership role in undergraduate curriculum

development. The current budget request shows SEE with only $8 million of the $35 million total in this area. Would you explain this? Can you tell us how much of the $4.5 million requested for curriculum development in R&RA in 1989 was actually spent on this? What is the current plan for the $11 million requested in R&RA for 1990?

ANSWER: With its responsibility for the administration of some programs and for the coordination and management of others, USEME's task, broadly, is to bring the resources of all of the NSF Directorates effectively to bear on the improvement of undergraduate education in all fields of concern to the Foundation.

In FY 1989 $2.9 million was awarded to Course and Curriculum proposals in the R&RA account. The $1.6 million shortfall over the target is due to the delayed issuance of the program solicitations. These funds were allocated to the closely related program, Instrumentation and Laboratory Improvement, which, as a result, exceeded its target by $2.7 million.

The FY 1990 Current Plan for Course and Curriculum is $16.3 million, $12.3 million in the R&RA account, and $4.0 million in the SEE account.

FUNDING PATTERNS

8. CONGRESSMAN MOLLOHAN: Why does NSF continue to scatter funds in an unclear way throughout the research directorates, making it difficult for Congress and the colleges and universities you serve to understand funding patterns?

ANSWER: The disciplinary research activities provide substantial support for education activities at the undergraduate level as we have clearly intended since the outset. This reflects our conviction that education and research priorities and needs are closely linked, and that the most effective educational activities will reflect the particular needs of specific disciplines. As is displayed on page R&RA-10, total proposed support for undergraduate education in FY 1991 is $134 million -- $84 million in the research directorates and $50 million in SEE - a 48 percent increase over the FY 1990 proposed level.

NEW BUILDING FOR SEE

9. CONGRESSMAN MOLLOHAN: There have been rumors that the overcrowding of NSF in its current headquarters has led to the suggestion that SEE move into another building. How is this consistent with your plan to increase the ties between the research and education missions of NSF?

ANSWER: There are no plans to move SEE into another building. At such time as a new headquarters building is selected, the entire Foundation will move into it.

COMPARISON OF STAFF INCREASES TO BUDGET INCREASES

10. **CONGRESSMAN MOLLOHAN:** How do the increases in staff sizes in R&RA and in SEE over the past few years compare to the increases in budget for the two areas?

ANSWER: Foundation-wide, increases in program funds have far exceeded the increases in staff size. While total NSF funding has increased almost 43 percent since 1986, total staffing has increased only about 8.5 percent. Of course, we have applied the modest staff increases to the areas experiencing the greatest growth both in terms of the size of the appropriation and the complexity of programs.

From 1986 to 1990, the Science and Engineering Education (SEE) Budget has increased 285%. Roughly 24 percent of the incremental increases to total NSF appropriations between FY 1986 and FY 1990 went into the SEE appropriation. Although the staff for the SEE Directorate has increased by 22 FTE, or 36 percent, from 61 FTE employees in 1986 to 83 in 1990, this increment represents 23 percent of NSF's total FTE increase for the period.

Program funds available in the Research and Related Activities (R&RA) appropriation have increased nearly 32 percent from 1986 to 1990. About 62 percent of the total increases to NSF appropriations since 1986 were for program funds in the R&RA appropriation. Although staff employed in the administration of R&RA funds has increased less than 6 percent, a total of 57 FTE, this increase represents 59 percent of NSF's total FTE increase for the period.

While total program funds have significantly outpaced staff increases, the proportion of the staff increases provided for each activity has been reasonably close to the proportion of increased funding provided for each appropriation. The small increases requested for FY 1991 are similarly consistent with the increased size and complexity of each program.

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN JIM CHAPMAN

NON-SCIENCE MAJORS

1. CONGRESSMAN CHAPMAN: Over the past several years, we have seen increased support and commitment to science and mathematics education. I am excited that this is a major focus of the NSF and feel you are on the right track in this regard. This year's budget request continues the support for programs in this area. For example, I see that programs like the Young Scholars Program for talented high school and middle school students who may be candidates for careers in science, math, and engineering will be expanded. However, I have another concern that I would like your thoughts on and that involves high school students who are non-science majors who live in an increasingly technological society. As our emerging technologies develop and are used by our industries, businesses, etc., large numbers of workers will be needed who understand basic math and science concepts. These future workers are today's math students and many of them are low achievers in science and math.

Has the NSF been involved in developing or has the NSF funded through any grants, programs which seek innovative ways to teach science and math skills to the average student population?

ANSWER: Put briefly, the answer to each of these three questions is yes. Since 1983 a major emphasis of the National Science Foundation programming in education has been to deepen the general understanding of mathematics, technology, and science on the part of all citizens -- present as well as future.

2. CONGRESSMAN CHAPMAN: Has the NSF explored the successes of courses designed to reach out to average students? For example, courses using applications-oriented or a hands on approach to learn science and math instead of more traditional science courses?

ANSWER: Research funded by the National Science Foundation in the late 1960's and through the 1970's demonstrated that instruction in activity-based programs at the elementary school level resulted in increased achievement in science, especially for students from disadvantaged backgrounds.

3. CONGRESSMAN CHAPMAN: If so, could you provide some information for the record on these programs and your findings?

ANSWER: These studies are summarized in the article, "The Effects of New Science Curricula on Student Performance", by Shymansky, Kyle and Alport, Journal of Research in Science Teaching, Vol. 20, pp. 387-404, May, 1983.

4. **CONGRESSMAN CHAPMAN:** Do you feel that targeting programs to a larger student population could help address the human shortfall you see developing in the sciences? For example, if innovative teaching methods are used to teach math and science to the average highschool students in the 50 percentile group, could we not only better prepare students for working in a highly technological society, but perhaps discover untapped interests and abilities in the sciences which could lead to more students pursuing science and math careers?

ANSWER: Yes, because the first of NSF's five education goals is " To help ensure that a high-quality education in science is available to every child in the United States, sufficient to enable those who are interested and talented to pursue technical careers at all levels, especially in science and engineering, as well as to provide a base for understanding by all citizens."

At the elementary and secondary school levels, NSF support is targeted on:

- enhancing the subject-matter competence of present and future teachers;
- conducting research on the processes of teaching and learning; developing indicators of student and teacher achievement, and better test instruments; and acquiring reliable information on educational trends and progress nationwide and in other industrialized nations;
- developing classroom materials that: reflect the state of scientific knowledge and its applications; are grounded in the best research on teaching and learning; will support the creation of several new, consistent, and coherent patterns of early science and mathematics education; and are well adapted to the differing needs of major segments of the student population;
- increasing the effectiveness and breadth of applications of advanced technologies to science and mathematics education; and
- implementing new research-based science and mathematics curricula in major school systems, and extending and networking the dissemination and exchange of information about successful curricula and instructional techniques.

5. **CONGRESSMAN CHAPMAN:** Do you see this as a role of the NSF to reach out to a larger non-science major student population or would this be the role of other agencies and departments?

ANSWER: The National Science Foundation has a role to play in improving the science literacy of all students. NSF's limited resources, in light of the total investment in the Nation's educational system, are invested to establish high quality, visible programs that can be adopted by any school to improve its math and science programs. Such improvement will be beneficial to students regardless of their personal interest in preparing for technical careers.

Currently there is considerable emphasis in Materials Development on materials that utilize a hands-on approach. This is particularly true in materials for elementary and middle school children. The report by the National Science Foundation to the Senate Appropriations Committee, "Evaluation and Dissemination of Precollege Teaching Materials", February, 1990, describes science materials for elementary and middle grades developed under the Publisher Initiative program. These projects are examples of activity-based instruction designed to improve the learning of all students in typical schools. A copy of the report is included for the record.

The Science and Engineering Education Directorate has undertaken special solicitations in the areas of elementary and middle school mathematics. Research indicates the importance of appropriate experiences for children in science and mathematics at the earliest grades. NSF is supporting materials development at the elementary and middle school levels, as well as at the secondary levels. These programs are intended to be effective across a full range of student abilities.

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN CHET ATKINS

SEWAGE TREATMENT

1. CONGRESSMAN ATKINS: I'd like to ask you a few general questions about the contribution that NSF may be able to make in the area of wastewater treatment research. According to the EPA, this country is facing an estimated $83.5 billion in wastewater treatment needs by the year 2008, and municipalities across the country will be forced to dramatically increase water and sewer bills to pay for these needs in the absence of federal support. The Environmental and Oceans Systems program has issued a number of grants in previous years that deal with wastewater treatment research. I was wondering if you could tell me how successful that research has been, and how valuable you think NSF-supported research can be in making wastewater treatment management more efficient and cost-effective?

ANSWER: The Environmental and Ocean Systems program at NSF has continued to support research on wastewater treatment which has been successful over the years as measured by adoption or implementation. Acceptability of innovations resulting from research in the wastewater treatment field is a relatively long-range matter. Since municipalities must usually borrow money to construct treatment plants, the process by which they select wastewater treatment concepts requires reasonable assurance that the innovative concept will perform in practice as well as it did during research and will continue to do so during the payback period for the borrowed funds.

Examples of NSF supported wastewater treatment research that have led to acceptance include the use of wetlands for the tertiary or advanced stage of treatment. This research that was conducted at the University of Michigan led to a successful demonstration project at Houghton Lake, Michigan funded through EPA's Construction Grants Program. This project successfully demonstrated that one way to conserve our wetlands is to utilize this natural technology for wastewater treatment as an alternative to physical and chemical, capital and energy intensive alternative processes. Cost of the research supported by NSF approximately equalled the initial capital-cost savings over the next, least-cost alternative. This project has since continued to provide the community with a cost-effective, economical solution to its problem as well as provide the confidence-base needed for other communities to accept and adopt it.

NSF support of research at Notre Dame on the Sequencing Batch Reactor (SBR) concept as an alternative to continuous flow systems was used as the basis of a demonstration project funded by EPA in which a continuous-flow, activated-sludge wastewater treatment plant in Culver, Indiana was converted to the SBR-mode of operation. This concept has been widely adopted in the U.S. and abroad. The Principal Investigator has since formed a consulting firm (SBR Technologies, Inc.) to market the concept domestically and abroad. It is especially applicable for small communities and by industrial firms not in proximity to large-scale systems that are most efficiently designed and operated in a continuous-flow mode.

NSF support of research at MIT on the use of a beam of energized electrons to disinfect sludge led to a large-scale experiment at Boston's Deer Island Wastewater Treatment Plant, the success of which led to installation of an electron-beam accelerator at the Miami-Dade Wastewater Treatment Plant on Florida's Virginia Key, funded under EPA's Innovative and Alternative Technology Construction Grants Program. After successfully demonstrating its capability to disinfect sludge, the unit was placed into a standby position for potential later use. This electron-beam accelerator is currently being used by the University of Miami and the Florida International Drinking Water Research Center for research supported by NSF on treatment of water and wastewaters that contain organic chemicals such as the polychlorinated biphenyls. This is being coordinated with continued research at MIT on a water treatment process involving radiation of water in the presence of polymers which may prove effective in adsorbing treatment byproducts and enhance their physical removal by sedimentation and filtration.

2. CONGRESSMAN ATKINS: Your budget request for Environmental and Ocean Systems is $5.9 million, an increase of $470,000 from the FY 90 level. Can you tell me how much of that request would go toward wastewater treatment related research, and whether, in your opinion, that is enough funding for what I consider to be one of the greatest research needs this country faces?

ANSWER: The Environmental Systems segment of the Environmental and Ocean Systems program for Fiscal Year 1989 made awards totalling $3.8 million, approximately half of which were allocated to research on water and wastewater treatment. The remainder of these funds were used to support research on environmental modeling, pollutant transport in surface and groundwaters, and related environmental issues including acid rain.

It is difficult to project the proportion of the program's increase for Fiscal Year 1991 that will be utilized for wastewater related research because the amount will depend on the quantity and quality of requests for support. Availability of two reports shortly expected from projects supported in Fiscal Year 1989 will provide a potential basis for determining future levels of funding that could be productively utilized to meet the Nation's research needs on environmental issues. These are the proceedings of the conference conducted by the Association of Environmental Engineering Professors on fundamental research directions in environmental engineering, and the proceedings of the American Academy of Environmental Engineering on environmental issues related to industrial competitiveness.

3. CONGRESSMAN ATKINS: I recently discussed wastewater treatment issues with a group of engineers from Camp, Dresser and McKee, one of the top environmental Engineering Firms in the country. One of the themes that they repeatedly raised is that we are increasingly being forced to look overseas for new wastewater treatment technologies because we simply are not developing them ourselves. Do you concur with that assessment and, if so, why is this taking place?

ANSWER: An important factor that impedes innovation in the water and wastewater treatment field is the previously cited need to have documented success of the innovation to satisfy requirements imposed by sources of funds borrowed to construct the resultant facilities. Communities, industries, and consulting engineers are not rewarded (and may be penalized) by assuming risks associated with adopting innovations before they are adequately developed and demonstrated. The role of development and demonstration of concepts emerging from research in the United States has been filled by companies that seek to profit from marketing innovations in which they have a stake. EPA has provided significant support of development and demonstration of concepts through its Office of Research and Development, and through the innovative and alternative and related aspects of its construction grants programs. It is hard to either agree or disagree with Camp, Dresser and McKee personnel regarding where they have to go to find new technologies that have been adequately developed. Concepts developed abroad sometimes seem more sophisticated and exotic for potential applications in the U.S., actual experience with which is found to be unwarranted.

4. CONGRESSMAN ATKINS: A number of engineers I've talked to say that another problem is that we're not crossing the bridge between research of new wastewater treatment technologies and actual demonstration projects and experimentation with those technologies. Does NSF do any tracking to see whether its research projects actually amount to anything and, if so, can you comment as to whether innovative wastewater treatment technologies developed through NSF grants are being tried out by municipalities?

ANSWER: Response to this question is partially developed in responses to the preceding questions. Of unquestionable accuracy is the statement that we are not providing an adequate "bridge" between research and the development/demonstration of new technologies.

ATKINS

This is, however a difficult problem stemming from the fact that research is the least expensive stage in a process that goes through research, development, demonstration and final acceptance. Development of a concept after the research stage can cost ten or more times as much as the research stage. It is therefore important to carefully select those concepts in which development is warranted.

NSF personnel engage in a limited amount of "tracking" to determine the value of research it has supported. Citations already made indicate significant acceptance of technologies for which NSF provided research-support and which were developed through demonstration and construction funding by EPA. An interesting acceptance by a municipality that did not involve EPA was one that resulted from NSF's Appropriate Technology Program in Fiscal Years 1980 and 81. This project at the University of Maryland found that it was possible to make bricks of excellent quality by use of sludge derived from treatment of domestic wastewater as an ingredient in the clay/shale/water mixture prior to extrusion and firing. The Washington Suburban Sanitary Commission arranged to have over 600,000 of these "Biobricks" made and has used them in several structures at their water and wastewater resource and treatment facilities in Montgomery and Prince Georges County, Maryland. One consideration that may have held up adoption is concern over the environmental impact of converting a regular brick manufacturing operation into one that uses sludge as an ingredient, especially sludge that may contain metals from domestic and industrial sources that are tributary to the wastewater collection system. A recent project supported by NSF at Purdue University investigated the possibility that eight metals of usual significance in this respect could be emitted. Metals considered were: cadmium, chromium, iron, lead, nickel, zinc, arsenic and selenium. Experimental results (Final Report of March 20, 1989, NSF Grant No. 86-07019) indicated that most of these metals would be trapped within the brick-matrix during firing and subsequent weathering.

An interesting example of a concept that emerged from NSF support of research that remains to be adequately developed is the combined use energized electrons for disinfection of sludge, pipe-line transport, and injection into soil on land dedicated for use in stabilizing the sludge and production of top-soil. NSF support of research on an injection concept innovated by Colorado State University has been widely adopted for placement of sludge into topsoil. This proof-of-concept experiment as a step toward development of this innovative concept of sludge management would cost an estimated $6-10 million over a period of 3-4 years.

EASTERN EUROPE

5. CONGRESSMAN ATKINS: I recently returned from a trip to Romania, where I learned that one of the most pressing problems

that country faces involves the astounding amount of pollution that must be cleaned up, and the equally astounding lack of information and resources the country possesses on environmental science and engineering. What is NSF currently doing, and what does it plan to do in FY 91, to help out not only Romania, but also Poland, Czechoslovakia and other Eastern European countries that are desparately seeking the means to clean up their environmental messes?

ANSWER: The National Science Foundation jointly funds cooperative scientific research projects and workshops with the countries of Romania, Poland, Czechoslovakia, Hungary and Bulgaria. Awards are granted to the most competitive proposals received from the research community after review for technical merit, overall balance and mutual benefit. Eligible topics reflect the priorities of our domestic programs and include a wide range of environment related subjects such as ecology, ecosystems, geography and regional development, paleoecology, and atmospheric sciences. Within this context, the Foundation and its foreign partners are able to respond to multiple opportunities for cooperative research efforts designed to address many of the fundamental problems underlying the wide-spread pollution conditions of Eastern Europe.

6. **CONGRESSMAN ATKINS:** What can NSF do to ensure that Romania and other Eastern European countries get the basic scientific materials, such as textbooks and journals, that will enable them to start educating their engineers about environmental restoration?

ANSWER: The National Science Foundation promotes information exchange by enabling U.S. scientists and engineers to work directly with East European counterparts in the framework of well focussed scientific projects. Awards for these activities may cover costs of pertinent journals and the publication of research results. We also encourage participation of young investigators and students. We find that permits the rapid dissemination of recent findings on environmental problems and other topics resulting from our research investments.

7. **CONGRESSMAN ATKINS:** Is NSF currently working with the United States Information Agency on any efforts to provide such materials to Eastern Europe?

ANSWER: NSF places emphasis on the performance of research in a direct, cooperative partnership. USIA places greater emphasis on information dissemination through printed and other media. We feel these efforts complement each other but address different needs. We are therefore not directly providing materials such as textbooks to East European countries, but we are planning to increase our support for joint research projects.

ATKINS

8. CONGRESSMAN ATKINS: You request a total of $12.08 million for International Cooperative Scientific Activities for FY 91, and $840,000 or a 7.5% increase over FY 90. Given the amount of change we've seen in Eastern Europe and the degree to which Eastern bloc countries will now be looking for help in environmental cleanup, will this increase enable NSF to properly expand upon its international activities?

ANSWER: This increase will permit a doubling of the number of research projects and workshops we support with East European countries. In addition, the broader changes effecting these countries will enable us to foster new, multilateral efforts on selected regional environmental topics. The dual approach should enable us to be very responsive to growing demands for help.

QUESTIONS SUBMITTED FOR THE RECORD
BY CONGRESSMAN SILVIO CONTE

REGULATION OF ANTARCTICA TOURISM

1. CONGRESSMAN CONTE: What is the extent and nature of the National Science Foundation's (NSF) regulatory authority for tourism in Antarctica by U.S. citizens?

ANSWER: NSF's broad mandate to manage the entire United States Antarctic Program, promote scientific study, and regulate the impact of human activity on the environment logically extends to the regulation of tourist travel both to and within Antarctica. Through Presidential directives, NSF has been charged with ensuring that the U.S. maintains "an active and influential presence" in the Antarctic, and overall management responsibility for planning, funding and implementing the U.S. national program in Antarctica resides in NSF.

As manager of McMurdo, Palmer, and South Pole Stations, NSF regulates access to these U.S. stations by tour operators and other tourist groups who properly notify NSF of pending visits under the Antarctic Treaty system.

The Antarctic Conservation Act provides NSF with express statutory authority to regulate environmental impacts of U.S. tourists in the Antarctic. Additional tourism authority, and the extent and nature of that authority, is further derived from the following: Antarctic Treaty, Agreed Measures for the Conservation of Antarctic Fauna and Flora, Antarctic Treaty Consultative Meeting (ATCM) Recommendations IV-27, VI-7, VII-4, VIII-9, and X-8, National Security Decision Memoranda 71 and 318, Executive Memorandum 6646, Memorandum of Agreement/Department of Defense and National Science Foundation, and NSF's regulations at 45 C.F.R. Part 670.

2. CONGRESSMAN CONTE: Has the NSF promulgated regulations that specifically control tourism by U.S. citizens in Antarctica? If not, why not?

ANSWER: NSF's regulations anticipate the need to enforce applicable statutes against U.S. citizens who, either as tourists or members of a scientific expedition, violate the law. In the event any U.S. tourist violates the Antarctic Conservation Act, or any NSF regulatory requirement for the protection of Antarctic flora and fauna, NSF's enforcement regulations at 45 C.F.R. Part 670, Subpart K, authorize the Foundation to prosecute that individual either administratively or judicially. Both civil penalties and criminal sanctions are provided for in the Act.

Regulations have also been published which require tour operators to distribute to their passengers and crew members materials describing prohibited conduct under the Antarctic Conservation Act. 45 C.F.R. 670.52(g). NSF's regulations also provide for the distribution of educational and other Antarctic information to tour operators, their clients and employees, and visitors. 45 C.F.R. 670.52(g).

Currently Antarctic Treaty Recommendation VIII-9 provides guidance for visitors to the Antarctic, affecting tourists and non-governmental expeditions in the Antarctic Treaty Area. It directs tourists to avoid disturbing wildlife and sets forth numerous provisions prohibiting certain activities. Those provisions are enforceable through the Antarctic Conservation Act and NSF's regulations at 45 C.F.R. Part 670, Subpart K.

NSF has not published regulations regarding specific travel or safety certifications in the Antarctic, but has been active in exploring those options. As a general rule, NSF discourages tourism for safety reasons and for the potential for interference with the scientific research program, as well as for environmental reasons. Further, emergency search and rescue operations will increase in proportion to the number of tourists travelling within Antarctica. The U.S. Antarctic Program has and will continue to engage in search and rescue operations whenever human life is endangered. Search and rescue teams operate, however, at the expense of the scientific program, and at risk to themselves. They may also incur legal liability for such "good samaritan" efforts. Regulation of tourism and its indirect encouragement, therefore, raises important policy issues that deserve considerable attention.

3. CONGRESSMAN CONTE: Do you see any conflict between NSF's authority under the Antarctic Treaty Act and NOAA's authority to regulate tourism of U.S. citizens as proposed under H.R. 3977, the Antarctic Protection and Conservation Act of 1990?

ANSWER: Yes, there is a potential conflict. H.R. 3977 unnecessarily duplicates NSF's authority under the Antarctic Conservation Act. For example, H.R. 3977 authorizes NOAA to issue regulations to "minimize and prevent adverse impact by tourists to the Antarctic environment." All of the factors listed for consideration in Section 5(b) of H.R. 3977 concern the environmental impacts of individual tourists in Antarctica.

Congress already provided the same statutory authority to NSF in the Antarctic Conservation Act, the purpose of which is "to provide for the conservation and protection of the fauna and flora of Antarctica" through a permitting process administered by NSF. NSF already has a regulatory program in place governing the environmental impacts of U.S. citizens in Antarctica. Both the Antarctic Conservation Act and H.R. 3977 reach virtually the same individuals and entities, whether applying the definition of "U.S. citizen" in the Antarctic Conservation Act, or the definition of "person" in H.R. 3977.

The only tourism authority within H.R. 3977 which arguably does not conflict with NSF's statutory authority under the Antarctic Conservation Act concerns tour group certification, training, and safety standards.

TOURISM AND ENVIRONMENTAL REGULATION

4. CONGRESSMAN CONTE: The Environmental Defense Fund, in a recent report, states that the "NSF should issue regulations pursuant to the Antarctic Conservation Act that prohibit U.S. citizens from engaging in, or U.S. tour operators from sponsoring, activities identified...as constituting 'harmful interference' with Antarctic wildlife." Do you agree with that statement?

ANSWER: We agree with the statement of the Environmental Defense Fund, and issued such regulations on February 16, 1989 as 45 CFR Part 670, entitled "Conservation of Antarctic Animals and Plants; Enforcement and Hearing Procedures; Tourism Guidelines, Final Rule." These regulations, issued to govern the administrative handling of alleged violations of the Antarctic Conservation Act of 1978, are part of the total set of regulations pursuant to the Act. The regulations do prohibit "U.S. citizens from engaging in or U.S. tour operators from sponsoring, activities identified ... as constituting 'harmful interference' with Antarctic wildlife."

Our major difference of opinion with EDF concerns the level of specificity necessary for NSF regulations to protect wildlife. EDF believes that a detailed listing of what constitutes "harmful interference" is preferable to the broad standard itself. NSF, on the other hand, believes that any listing, no matter how inclusive, would leave out forms of harmful interference which should be prohibited. In that manner NSF can continually evaluate and apply better protection to wildlife based on new and evolving scientific evidence of harmful impacts.

5. CONGRESSMAN CONTE: The EDF also states that "NSF should issue regulations that clarify the 'taking' prohibitions of the Antarctic Conservation Act and identify specifically what activities may 'harm', 'molest', or 'harass' Antarctic wildlife." Do you agree or disagree?

ANSWER: We believe that the regulations should remain broad in their definition of "taking," "harming," "molesting," and "harassing." The regulations are intentionally broad because the spectrum of human activities that can fall into any of these categories also is broad and will vary somewhat from species to species. The strength of the regulations is in the breadth of activity they cover.

REGULATORY EXPENSE

6. CONGRESSMAN CONTE: How much does the Division of Polar Programs expend on regulatory oversight in Antarctica?

ANSWER: The Division manages regulatory requirements related to safety, the environment, and health through its Safety, Environment and Health Office and its Safety, Environment and Health Implementation Team operations. Permitting under the Antarctic Conservation Act is also regulated by the Division. In addition, NSF's Office of the General Counsel provides additional legal and related support for all of DPP's regulatory responsibilities.

The Division spends about $100,000 per year on regulatory oversight, but substantially more than that is spent handling tour visits to its stations. Included in this amount are materials to educate tourists on their responsibilities under the Antarctic Conservation Act.

7. CONGRESSMAN CONTE: What percentage is this of your Antarctic scientific program?

ANSWER: Tourism and permitting oversight is equal to roughly one half of one percent of the cost of the U.S. Antarctic Research Program

REGULATORY OVERSIGHT OF TOURISM

8. CONGRESSMAN CONTE: Which agency, NSF or NOAA is better suited to provide regulatory oversight to U.S. activities in Antarctica, particularly tourism?

ANSWER: Clearly the National Science Foundation is better suited to provide regulatory oversight to U.S. activities in Antarctica. The Foundation's activities to date demonstrate it can effectively influence tourist behavior and it has in place logistic systems and stations adequate to perform the necessary tasks. In the past, NSF has carried out its responsibilities through other federal agencies where appropriate.

FUNDING FOR SECTION 5 H.R. ~~3977~~

9. CONGRESSMAN CONTE: Based on NSF experience, how much funding would be required each year for the next five years to implement Section 5 of H.R. 3977?

CONTE

ANSWER: Between $500,000 and $1 million per year might be required to implement Section 5 of H.R. 3977. However, the viability of unilateral U.S. measures is open to serious question.

NATIONAL ENVIRONMENTAL POLICY ACT

10. CONGRESSMAN CONTE: Do you believe the provisions of NEPA currently apply to the activities of the National Science Foundation in Antarctica?

ANSWER: The National Science Foundation has determined that NEPA does not apply to agency actions in Antarctica. In a report to the Director of NSF, entitled "A National Science Foundation Strategy for Compliance with Environmental Law in Antarctica," NSF's Office of the General Counsel concluded that Executive Order 12114 -- not NEPA -- applies to NSF actions in the Antarctic.

The Executive Order resolves, at least for Executive agencies, the long-standing debate within both Congress and the Executive Branch on the issue of NEPA's extraterritorial applicability. The Order "represents the United States government's exclusive and complete determination of the procedural and other actions to be taken by Federal agencies to further the purpose of the National Environmental Policy Act, with respect to the environment outside the United States, its territories and possessions", and mandates many of the same procedural and substantive requirements contained in NEPA.

11. CONGRESSMAN CONTE: Do you believe that the provisions of NEPA apply to any of the activities of U.S. citizens in Antarctica?

ANSWER: The National Science Foundation has determined that NEPA does not apply to agency actions in Antarctica. Since the statutory obligations set forth in NEPA apply to Federal agencies only, we assume NEPA does not apply to individual U.S. citizens unaffiliated with major federal actions-- regardless of their location.

Environmental assessment provisions contained in the Antarctic Treaty Code of Conduct, Agreed Measures, and other Treaty recommendations, however, apply to activities of the United States (as a contracting party) and its citizens. Consequently, provisions already exist which require Treaty nations and their citizens to conduct the same type of assessments and impact statements presently required under NEPA.

CONTE

NSF AND ENVIRONMENTAL LAWS

12. CONGRESSMAN CONTE: Does NSF consider that other major environmental laws, such as the Clean Water Act, Clean Air Act, and the Resource Conservation and Recovery Act (RCRA) apply to its activities in Antarctica? If not, why not? Does NSF oppose their application in Antarctica? Why, or why not?

ANSWER: The Antarctic Conservation Act (ACA) comprehensively governs all actions by federal officials and United States citizens that have an impact upon the Antarctic environment. The Act prohibits the discharge of any harmful substance in Antarctica, except pursuant to a valid NSF permit. Congress wisely chose not to overlay domestic environmental statutes and state-based permitting requirements on top of the ACA regime.

NSF's Office of the General Counsel recently evaluated all of the major international and domestic environmental laws in NSF Document 90-4, "A National Science Foundation Strategy for Compliance with Environmental Law in Antarctica." NSF determined that most of the requirements of the Clean Water Act, Clean Air Act, RCRA, and certainly the joint federal/state permitting programs that are the heart of those statutes, do not apply to operations in Antarctica. Moreover, wholesale imposition of those laws, as currently written, makes no sense in the Antarctic context. For example, even the most stringent air pollution standards and monitoring programs articulated under the "prevention of significant deterioration" guidance for the national parks within the United States would allow far more emissions in Antarctica than currently exist or would be advisable. Imposition of advanced forms of wastewater treatment that include chemical processing might actually harm the environment more than discharges after maceration and dilution -- the treatment recommended by the Scientific Committee on Antarctic Research (SCAR).

NSF believes that implementation of sound environmental practices under its Safety, Environment and Health initiative, together with the Antarctic Conservation Act, will further improve U.S. environmental practices in Antarctica. The ACA expressly implements environmental mandates and accords under the Antarctic Treaty, and the principles of sound environmental practices established by SCAR or articulated in domestic requirements which can be translated into Antarctic standards and controls. Additional legislative regulatory authority would be unnecessarily duplicative. Moreover, NSF also opposes efforts to dramatically rewrite domestic environmental laws such as RCRA, Clean Water Act, and Clean Air Act, in order to force-fit those laws to Antarctica.

A great deal of progress has already been made in improving environmental practices in Antarctica. For example, over the past two years NSF retrograded from Antarctica some 1,120 drums of hazardous, toxic and other waste accumulated over 30 years of program activity. This past austral summer, McMurdo Station segregated plastic, glass and metals for the first time, and retrograded the solid waste for disposal and recycling. NSF no longer practices ice-staging of solid waste for disposal at sea, and present policy prohibits all ocean dumping without first obtaining the appropriate regulatory permits from EPA.

In addition to these efforts already underway, NSF also plans improvements in the following areas:

o Hazardous Material Management -- a cradle-to-grave management plan is being implemented.

o Wastewater Treatment -- construction of submerged outfalls at McMurdo and Palmer is planned for wastewater discharge after maceration and dilution.

o Control of Air Emissions -- incineration requirements will be examined, and an incinerator will be installed at McMurdo.

o Solid Waste System Improvements -- increased retrograding of waste from U.S. stations, improved handling and managing procedures, and waste inventory and minimization studies will all be implemented.

o Oil Spill Prevention -- a complete Spill Prevention and Countermeasures Control plan is being written. Replacement of fuel bladders, upgrade of containment systems and berms are planned.

USER FEES FOR REGULATING TOURISM

13. CONGRESSMAN CONTE: With respect to Section 5 of H.R. 3977, what opportunities do you see for the government to charge user fees to cover the costs of regulating tourism?

ANSWER: User fees would be an appropriate source of income, although failure to establish an international system would unfairly and unnecessarily disadvantage U.S. tour operators who have set an exemplary standard in Antarctica.

14. CONGRESSMAN CONTE: Assuming H.R. 3977 was enacted as introduced, would the federal government require further statutory authority to charge user fees? Please submit such language.

ANSWER: The federal government would probably not require further statutory authority to charge user fees. However, language for this follows:

The Director may establish and charge fees to cover the costs of regulating tourism. The amount of such fees shall be commensurate with the administrative costs incurred by the Director in undertaking such regulation.

MINERAL PROSPECTING

15. CONGRESSMAN CONTE: What are the prospects for mineral development in Antarctica?

ANSWER: The nature of Antarctica, characterized by extreme cold and severe weather for most of the year, has limited its continuous occupation to a small number of government-operated stations for which everything is imported. While the continent is known to contain small deposits of minerals, all but about 2% of its surface is covered by ice most of which is a mile or more thick. Offshore activities would also be impeded by the generally rapid drop off of the continental shelf, ice cover and icebergs. All of this suggests that mineral development is unlikely for many years. The recent study completed by OTA provides a more detailed analysis of this issue.

16. CONGRESSMAN CONTE: Is the National Science Foundation funding any scientific research activity within the meaning of article III of the "prospecting" as defined by H.R. 3977?

ANSWER: No, the Foundation is not funding any such research activity.

17. CONGRESSMAN CONTE: How are the data from these activities shared with other Antarctic Treaty Consultative Parties?

ANSWER: As stated above, the NSF does not fund any activity that would be considered prospecting. Therefore, no data are generated.

Results of the scientific research activities that NSF does fund are shared in several ways: through publication in professional journals, through submission to national data banks such as the National Oceanographic Data Center, and through individual requests to the investigator. Data can be obtained from national data banks by anyone for a nominal cost.

18. CONGRESSMAN CONTE: What countries are currently carrying out mineral "prospecting" as defined in H.R. 3977 as scientific research activities?

ANSWER: It is impossible to state with any certainty what countries, if any, are currently carrying out mineral "prospecting" as scientific research activities. Virtually the same geological and geophysical techniques are used for both scientific research in the earth sciences and "prospecting." The only differences would be the objective or objectives for the collection of the data and how the information is utilized once it is obtained.

19. CONGRESSMAN CONTE: How do you obtain their data?

ANSWER: We obtain the scientific research results from other nations through the Scientific Committee for Antarctic Research and its panels, direct request to the scientists who performed the work and through the published literature. Unfortunately, some of the data from other countries have not been made available in forms useful for further study.

20. CONGRESSMAN CONTE: How could significant mineral development in Antarctica adversely affect scientific research?

ANSWER: While it is difficult to evaluate efforts of unknown future mineral development on science, protection of research sites from direct and indirect effects of minerals development will be important. Under Antarctic Minerals Convention, there is a provision that no activities should take place which would pose a significant threat to scientific research activism.

CLEAN UP PLANS

21. CONGRESSMAN CONTE: What plans does NSF have to clean up waste dump at McMurdo and Palmer Stations?

ANSWER: Extensive cleanup at both stations has taken place. The dump at Palmer Station has not been used since 1987. Materials formerly dumped are stored in shipping containers and are returned to South America. The dump at McMurdo Station, which serves an area with about 20 times the population of that of Palmer, is one subject of a solid waste management study being undertaken for NSF by the Argonne National Laboratory. Argonne is to examine a range of activities from minimization of waste to incineration and retrograde to determine the combination of measures that maximize program effectiveness and environmental protection.

Future plans for the cleanup program are described in "Implementation of the National Science Foundation's Strategy for Compliance with Environmental Law in Antarctica." The detailed decisions concerning the degree of cleanup of waste dumps will be based on a comprehensive program including preliminary assessment, site investigation, remedial investigation, feasibility studies, remedial design, and remedial action.

22. CONGRESSMAN CONTE: How much will this cost? How much are you budgeting in FY 1991? How much will you spend in 1991?

ANSWER: The initial on-site evaluation of the cleanup effort is scheduled for the 1990 to 1991 austral summer. As the evaluation has not been conducted, no detailed estimates of total costs have been made for the complete cleanup of waste dumps. NSF has requested $5 million in FY 1991 for cleanup efforts, and longer-range measures to deal with solid wastes.

23. CONGRESSMAN CONTE: When does NSF plan to phase out open burning of wastes at these stations? When does NSF plan to phase out landfills at these stations?

ANSWER: NSF eliminated open burning at Palmer Station in 1987. NSF plans to eliminate open burning at McMurdo Station within five years. Detailed milestones for McMurdo Station are stated in the "Implementation of the National Science Foundation's Strategy for Compliance with Environmental Law in Antarctica."

NSF has not used the solid waste landfill at Palmer Station since 1987. Phase out of this practice at McMurdo Station is being examined as part of the integrated waste management study, which will examine all the alternatives for managing solid waste at McMurdo Station including waste minimization, recycling, retrograding, and then incinerating any remaining wastes. If incineration is required, options for ash management will be evaluated. Cessation of landfill operations at McMurdo, however, currently is infeasible.

RETROGRADE OF ANTARCTIC WASTE

24. CONGRESSMAN CONTE: How much solid waste does NSF now retrograde to the U.S. and how much money and equipment is required to retrograde all solid waste to the U.S.?

ANSWER: NSF retrogrades about 1 million pounds of items to the United States each year. Almost everything except for combustible materials and the resulting ash is retrograded to the U.S., including: old motors, old vehicles, scrap metal, aluminum cans, glass, plastics, and all hazardous waste. Estimated cost of 100% retrograde will be included in the solid waste management study.

PRECAUTIONS AGAINST OIL SPILLS

25. CONGRESSMAN CONTE: What steps has NSF taken to ensure that U.S. vessels supporting U.S. programs in Antarctica won't spill oil and damage the environment, like the Argentine supply ship, Bahia Paraiso did last year? What damage, if any, was done to U.S. research experiments and marine life as a result of this spill?

ANSWER: NSF is convinced that the ships involved in the U.S. Antarctic Program are operated with the level of seamanship necessary to avoid a Bahia Paraiso-type accident. Also, most of the fuel for the U.S. Antarctic Program is transported by "Champion Class" tanker ships. The Champion Class ships' fuel cargo compartments are protected from rupturing, should grounding occur, by both doublebottom and wing tanks dedicated exclusively to ballast water. In addition special precautions are taken during spill-vulnerable operations, such as the unloading of fuel, including continuous monitoring and the use of containment booms. A complete Spill Prevention and Countermeasures Control plan is presently being written, and oil spill prevention equipment has already been transported to both McMurdo and Palmer station.

With respect to impact on science projects, immediate impacts were as follows:

- Two science projects underway at the time of the accident (mortality in bird populations South Polar Skuas and Blue-eyed Shags) had to change their foci from population biology and ecology to an assessment of the effects of the oil spill.
- Three funded projects were cancelled for lack of logistical support. (Palmer Station and the RV Polar Duke were involved in clean-up activities).

COORDINATION OF ENVIRONMENTAL COMPLIANCE REPORT

26. CONGRESSMAN CONTE: Has NSF coordinated its environmental compliance report and clean-up plan with other agencies like the EPA and CEQ? If so, what do they think of the plan?

ANSWER: NSF provided EPA and CEQ draft copies of its environmental compliance report, "A National Science Foundation Strategy for Compliance with Environmental Law in Antarctica," and requested comments from both agencies. NSF also solicited comments on the draft from all member agencies of the Antarctic Policy Group (APG), concerned environmental groups, and members of the public. NSF briefed EPA staff several times as well as the APG member agencies and numerous environmental groups. In each instance NSF encouraged substantive comments, changes, or suggestions prior to issuance of the final Report. An earlier

NSF document, entitled "Environmental Protection Agenda," was also made available to the public, and comments on this on-going management plan were solicited in the Federal Register.

As a result of this coordination, many changes were made to the report. The comments incorporated in the final legal compliance document included those provided by EPA's program offices. EPA's Office of General Counsel was unable to provide NSF with official written comments within an extended comment period. All of NSF's legal compliance determinations, however, are consistent with past Department of State positions on applicable law in Antarctica. There were no objections by EPA or CEQ to any of the preventative or remedial measures contained in the legal compliance report. CEQ's only comment concerned NEPA, requesting NSF not to take a position on whether the statute has extraterritorial applicability despite the clear language of Executive Order 12114.

National Science Foundation

WASHINGTON, D.C. 20550

Justification of Estimates of Appropriations to the Congress

Fiscal Year 1991

TABLE OF CONTENTS

BUDGET SUMMARY .... NSF SUMMARY - 1

RESEARCH AND RELATED ACTIVITIES .... R&RA - 1

BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES .... BBS - 1

Molecular Biosciences .... BBS - 7
Cellular Biosciences .... BBS - 11
Biotic Systems and Resources .... BBS - 15
Behavioral and Neural Sciences .... BBS - 19
Social and Economic Science .... BBS - 23
Instrumentation and Resources .... BBS - 27
Science and Technology Centers .... BBS - 31

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING .... CISE - 1

Computer and Computation Research .... CISE - 9
Information, Robotics and Intelligent Systems .... CISE - 13
Microelectronic Information Processing Systems. .... CISE - 17
Advanced Scientific Computing .... CISE - 21
Networking and Communications Research and Infrastructure .... CISE - 25
Cross-disciplinary Activities .... CISE - 31
Science and Technology Centers .... CISE - 35

ENGINEERING .... ENG - 1

Biological and Critical Systems .... ENG - 9
Chemical and Thermal Systems .... ENG - 15
Electrical and Communications Systems .... ENG - 19
Mechanical and Structural Systems .... ENG - 23
Design and Manufacturing Systems .... ENG - 27
Engineering Centers .... ENG - 31
Engineering Infrastructure Development .... ENG - 37

GEOSCIENCES .... GEO - 1

Atmospheric Sciences .... GEO - 5
Earth Sciences .... GEO - 11
Ocean Sciences .... GEO - 15
Arctic Research Program .... GEO - 21
Science and Technology Centers .... GEO - 25

MATHEMATICAL AND PHYSICAL SCIENCES .... MPS - 1
- Mathematical Sciences .... MPS - 7
- Astronomical Sciences .... MPS - 13
- Physics .... MPS - 21
- Chemistry .... MPS - 27
- Materials Research .... MPS - 31
- Science and Technology Centers .... MPS - 37
- Major Research Equipment .... MPS - 41

RESEARCH FACILITIES MODERNIZATION .... RFM - 1

SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS .... STIA - 1
- Science Resources Studies .... STIA - 7
- Policy Research and Analysis. .... STIA - 11
- Research Initiation and Improvement .... STIA - 13
- Industrial Science and Technological Innovation .... STIA - 17
- International Cooperative Scientific Activities .... STIA - 21

PROGRAM DEVELOPMENT AND MANAGEMENT .... PDM - 1

NSF HEADQUARTERS RELOCATION .... NHR - 1

UNITED STATES ANTARCTIC PROGRAM .... USAP - 1
- U.S. Antartic Research Program .... USAP - 5
- Operations Support. .... USAP - 9
- Major Construction and Procurement .... USAP - 15

SCIENCE AND ENGINEERING EDUCATION .... SEE - 1
- Teacher Preparation and Enhancement .... SEE - 7
- Materials Development Research and Informal Science Education .... SEE - 11
- Undergraduate Science, Engineering and Mathematics Education .... SEE - 15
- Research Career Development .... SEE - 19
- Studies and Program Assessment .... SEE - 23

OFFICE OF THE INSPECTOR GENERAL .... OIG - 1

QUANTITATIVE DATA TABLES .... QDT - 1

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

FY 1991
BUDGET SUMMARY

(DOLLARS IN THOUSANDS)

New Obligational Authority:

FY 1991 Budget Request	$2,383,000
FY 1990 Appropriations (P.L.100-144)	2,083,608
Increase in New Obligational Authority	$299,392

Program Level:

FY 1991 Budget Request	$2,383,000

FY 1990:

Appropriations (P.L.100-144)	$2,083,608
Plus 1989 Carryover	38,183
FY 1990 Program Level	$2,121,791
Increase in Program Level FY 1991/90	$261,209

SUMMARY OF FY 1991 BUDGET BY APPROPRIATION AND ACTIVITY (Dollars in Thousands)

	ACTUAL FY 1989	REQUEST FY 1990	ESTIMATE FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
RESEARCH AND RELATED ACTIVITIES					
Biological, Behavioral and Social Sciences	$281,469	$314,500	$293,705	$327,525	$33,820
Computer and Information Science and Engineering	151,838	191,200	169,881	193,250	23,369
Engineering	187,065	211,200	200,358	226,000	25,642
Geosciences	309,909	341,300	325,200	383,725	58,525
Mathematical and Physical Sciences	503,803	553,500	594,320	621,500	27,180
Research Facilities Modernization	0	0	0	20,000	20,000
Science and Technolgy Centers	0	20,000	0	0	0
Scientific, Technological and International Affairs	58,311	67,322	63,515	74,000	10,485
Program Development and Management	91,286	104,000	96,383	102,500	6,117
NSF Headquarters Relocation	0	0	0	5,500	5,500
Subtotal	1,583,681	1,803,022	1,743,362	1,954,000	210,638
Unobligated Balance Available Start of Year	(616)	0	(37,951)	0	37,951
Unobligated Balance Available End of Year	37,951	0	0	0	0
Adjustments to Prior Year Accounts	(566)	0	0	0	0
Unobligated Balance Lapsing	50	0	0	0	0
Research and Related Activities Appropriation	1,620,500	1,803,022	1,705,411	1,954,000	248,589
ACADEMIC RESEARCH FACILITIES APPROPRIATION	0	0	19,690	0	(19,690)
SCIENCE AND ENGINEERING EDUCATION ACTIVITIES APPROPRIATION					
Teacher Preparation and Enhancement	63,662	68,500	81,061	89,600	8,539
Materials Development, Research and Informal Science Education	43,986	49,000	48,000	61,500	13,500
Undergraduate Science, Engineering and Mathematics Education	27,999	30,000	34,000	50,000	16,000
Research Career Development	30,980	38,000	36,900	44,900	8,000
Studies and Program Assessment	4,500	4,500	4,365	5,000	635
Subtotal	171,127	190,000	204,326	251,000	46,674
Unobligated Balance Available Start of Year	(44)	0	(61)	0	61
Unobligated Balance Available End of Year	61	0	0	0	0
Adjustments to Prior Year Accounts	(189)	0	0	0	0
Unobligated Balance Lapsing	45	0	0	0	0
Science and Engineering Education Activities Appropriation	171,000	190,000	204,265	251,000	46,735
U.S. ANTARCTIC RESEARCH PROGRAM ACTIVITIES					
U.S. Antarctic Research Program	15,572	17,500	17,016	19,000	1,984
Antarctic Operations	88,497	102,200	19,812	110,000	90,188
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704
Subtotal	131,069	156,000	72,124	175,000	102,876
Unobligated Balance Available Start of Year	(153)	0	(171)	0	171
Unobligated Balance Available End of Year	171	0	0	0	0
Adjustments to Prior Year Accounts	(87)	0	0	0	0
U.S. Antarctic Program Appropriation	131,000	156,000	71,953	175,000	103,047
U.S ANTARCTIC LOGISTICAL SUPPORT ACTIVITIES APPROPRIATION	0	0	79,729	0	(79,729)
OFFICE OF INSPECTOR GENERAL APPROPRIATON	0	0	2,560	3,000	440
TOTAL, NSF APPROPRIATION	$1,922,500	$2,149,022	$2,083,608	$2,383,000	$299,392

1/ FY 1990 Estimate includes carryover unobligated balances from 1989.
See explanation of carryover 1989.

NATIONAL SCIENCE FOUNDATION
FY 1991 BUDGET REQUEST

OVERVIEW

The National Science Foundation (NSF) Budget Request for FY 1991 is $2.38 billion, an increase of $299 million or 14.4 percent over the FY 1990 Current Plan. The request includes the following appropriations:

(Millions of Dollars)

Account	FY 1990 Current Plan	FY 1991 Request	Change 90/91	Percent Increase
Research and Related Activities	$1,725.1	$1,954.0	$228.9	13.3%
U.S. Antarctic Program	151.7	175.0	23.3	15.4
Science and Engineering Education	204.3	251.0	46.7	22.9
Office of Inspector General	2.6	3.0	0.4	17.2
Total, NSF	$2,083.6	$2,383.0	$299.4	14.4%

The FY 1991 Budget signals the start of NSF's fifth decade. In NSF's early years, the country's concerns focused on science and engineering education and research in order to maintain an advantage over a military adversary. Today, education and research remain critical to the country's well-being, not only in terms of national security, but also in terms of economic security. Now,as then, NSF plays a vital role in generating and disseminating new knowledge and supporting the education of a technical workforce.

Because of the central role of research and education in the country's future and despite severe budgetary constraints, the President's plan to double the Foundation's budget is an important investment in the nation's future. This budget provides the funds to bolster significant support for the nation's research infrastructure, thereby strengthening our nation's ability to compete in the world's economy.

In international competition the comparative advantage is no longer determined by access to low wage areas or access to natural resources but by access to sophisticated knowledge and new discoveries and inventions. NSF plays a key role in initiating and stimulating innovative research and developing the knowledge base and educated people necessary to increase our productivity and improve our economic competitiveness. Recent NSF initiatives in biotechnology, supercomputing, and the development of new materials have had major impacts on improving our competitive posture as well as in advancing the knowledge base.

The FY 1991 Request proposes to accelerate global change research, enhances support for disciplinary research, continues growth for the U.S. Antarctic Program Safety, Environmental and Health initiative, and takes advantage of unique scientific opportunities for international, as well as interagency, cooperation.

Equally important, the FY 1991 Request calls for significant growth in education and human resources. NSF plays a key role in the education of the next generation of scientists, engineers and science educators. In FY 1991 the Foundation will support over 28,000 graduate and undergraduate students at some 1200 colleges and universities. In an effort to reverse the downward trend in the number of science and engineering baccalaureates, NSF is investing significantly in precollege and undergraduate education, programs to attract and retain minorities, women and the disabled, and support for new researchers.

The education of future scientists and engineers and the development of new knowledge and its transfer to others are critical to new technologies, products and an improved competitive posture. The FY 1991 Request reflects a strategic framework for a significant and balanced investment in education, the generation of new knowledge, and the transfer of new knowledge from producers to users. It emphasizes support of science and engineering research and education at U.S. universities and colleges, which are the primary source of our technical workforce and the major performers of basic research.

NSF STRATEGY

The FY 1991 Request centers around two strategic themes:

- **Strengthening the research base and improving academic facilities and equipment ($1.81 billion).**

  Support for research and facilities is the dominant mode of NSF support. The FY 1991 budget request for these activities is $1.81 billion, an increase of over 11 percent ($183 million) over the prior year. All major fields of physical and life sciences, engineering and computer sciences, as well as the behavioral and social sciences, are represented through grants to individual and groups of investigators, support of undergraduate and graduate students and postdoctoral researchers, and support for laboratory instrumentation and access to large, specialized centers and facilities, computers, and computer networks.

  Equipment is as necessary a requirement for research as are human resources. The cost of equipment is increasing at a faster rate than inflation, and in many of the sciences, is today beyond the reach of an individual country. Major benefits of sharing such equipment include the more equitable sharing of results between us and our trading partners and the access to scarce resources. For these reasons, we are establishing a joint partnership in the design, construction and operation of new optical telescopes and gravity wave detectors on an international basis. This budget contains the first installment for this new equipment.

  The FY 1991 Request continues the program established in FY 1990 to modernize and improve scientific and engineering research facilities in our colleges, universities, and other institutions.

- **Developing human resources, broadening participation, and improving science and engineering education at all levels ($463 million).**

  The FY 1991 request for education and human resources is $463 million, an increase of 30 percent ($106 million) over the FY 1990 Current Plan. These activities are supported across all areas of the Foundation, recognizing the full spectrum of education and training necessary to sustain the science and engineering education pipeline. This focus on the total pipeline, from kindergarten through postdoctoral training, addresses the loss of students at numerous educational levels.

	FY 1990 Current Plan	FY1991 Request	Change 90/91	Percent Increase
Research and Facilities	$1,627	$1,809	$182	11.2%
Education and Human Resources	357	463	106	29.6

RESEARCH AND FACILITIES

Support for research and facilities continues to be the primary focus of NSF support, accounting for over 75 percent ($1.8 billion) of the FY 1991 budget request. This represents an increase of more than 11 percent over FY 1990 levels.

Continued growth is requested for such forefront, high-priority areas as genetics, biodiversity, materials research, the global change research initiative, arctic research, manufacturing and software engineering research. Many of these areas reflect the growing complexity and multi-disciplinary nature of today's research problems, evidenced by increased coordinated research, shared data and common instrumentation and equipment. And increasingly, the advantages realized by collaborative relationships, scale or unique facilities span agency and national borders. Highlights include:

- The expansion of the President's U.S. Global Change Research Program that seeks to understand, and ultimately predict, future changes in the earth's environment, such as global warming. In FY 1991, NSF support will roughly double, to $103 million. As one of seven federal agencies engaged in this initiative, NSF focuses its support on the basic research necessary to understand and model the Earth's component systems, particularly climate and hydrologic cycles, biosphere's response to climate change, land-margin ecosystems, human dimensions of global change and database establishment and management.
- A joint NSF/USDA/DOE/NIH effort to map and sequence a plant genome. This multidisciplinary research will involve biochemists, geneticists, and computer scientists, and will provide model tools and techniques to facilitate the sequencing of more complex genomes. NSF will also seek co-funding with our international partners.

- Funding for a second class of 10-12 Science and Technology Research Centers, deferred from FY 1990 due to a constrained Research and Related Activities budget.

The Foundation, long a source of support for unique national facilities such as telescopes, research ships, and supercomputers, will respond to several new opportunities in FY 1991 to provide investigators with access to world-class facilities. Three projects in particular demonstrate the Foundation's significant commitment to maintaining U.S. preeminence in gravitational physics and ground-based astronomy, while at the same time leveraging considerable international and interagency support. Highlights include:

- The opportunity to verify and measure the existence of gravitational waves and black holes, thus opening a new window onto the Universe, are objectives of Cal Tech and MIT scientists designing the Laser Interferometer Gravitational Wave Observatory (LIGO). NSF will begin construction of two identical, but widely separated, next-generation detectors in FY 1991, at a total estimated cost of $192 million over four years. Two European groups (United Kingdom/Germany and France/Italy) are planning to build detectors of compatible design and similar costs to the LIGO facility. These detectors, working in concert with LIGO, will permit systematic astrophysical observations in the new field of gravitational wave astronomy. Such international cooperation provides a major opportunity to lower national cost by sharing development, construction and operational expenses necessary to begin research in an entirely new field.
- Recent technological advances in key areas of telescope construction present the opportunity to push telescope performance to new standards of excellence and build facilities that will support qualitatively new kinds of science. Construction of two 8-meter optical/infrared telescopes, one in each hemisphere, will be jointly funded by the U.S. and the United Kingdom and Canada as prospective partners. Design and initial purchase of glass for mirrors will take place in FY 1991, followed by start of construction of the first 8-meter telescope in the northern hemisphere in FY 1992. The project is estimated to take 8 years to complete at a total cost of $176 M, of which the U.S. will provide half.
- New technology in antenna design will significantly improve the performance of the 1000-foot diameter reflector at the Arecibo, Puerto Rico, Observatory. NSF and NASA will split the cost of the two-year, $22 million upgrade.

EDUCATION AND HUMAN RESOURCES

Scientific, technical and economic progress requires careful attention to developing the future pool of human talent. While NSF support for education and human resources spans the education pipeline from grade school through graduate school and research initiation, the FY 1991 Request focuses on activities directed at strategic points in the educational sequence, with a primary goal of attracting and retaining students from populations traditionally underrepresented in the sciences.

The FY 1991 Request includes over $460 million for education and human resource development, an increase of 30 percent, or $106 million over FY 1990. Of this total,

$335 million is for education activities and $128 million for other human resource development activities, such as awards to new investigators and studies and analyses. A summary of NSF's investment by education/professional level, in millions of dollars, is below.

Level	FY1990	FY1991	Increase
K-12	$140M	$165M	17.8%
Undergraduate	90	134	48.4
Graduate/Postdoc/Professional	127	164	29.1%

While education and human resource development efforts take place across all Activities and programs of the Foundation, the preponderance of precollege education activities is located in the Science and Engineering Education Activity. Current pre-college efforts to improve teaching, materials and informal science education will be complemented by enhanced efforts to forge strong federal-state partnerships to improve lower, middle and high school science and mathematics education across the country.

Undergraduate research and education programs, supported by every Activity, will increase $44 million (48 percent) to a total of $134 million in FY 1991. Key components of this educational thrust are:

- A significant investment in comprehensive curriculum redesign to encompass introductory science, mathematics and engineering courses in all Activities, and Engineering Education Coalitions focusing on comprehensive engineering curriculum reform; and
- An increase in the number of Career Access centers to about 16 in FY 1991 to reduce the loss of talented minority and women students in science, mathematics and engineering.

New Graduate Fellowships will be increased by 100 offers, to a total of 1100. This represents a doubling of Graduate Fellowships over the FY 1987 level, as well as of the Women in Engineering fellowships component over the FY 1990 level (from 80 to 160).

An emerging need is for scientists and engineers trained across traditional disciplinary boundaries. New and enhanced programs to address this need include:

- The Global Change Research Education and Training Program, a new program in FY 1991, which will support approximately 40 postdoctoral appointments, 80 graduate students and 200 undergraduate students as research participants on interdisciplinary global change research problems; and
- Research Training Group awards, which support new or significantly enhanced multidisciplinary training programs at Ph.D.-granting institutions.

Ensuring opportunities for new investigators, as well as encouraging the research careers of young investigators and those new to NSF, is an area of enhanced support in

FY 1991. Special postdoctoral programs in high-need areas such as mathematics, chemistry, environmental biology and plant sciences will receive special attention. The Presidential Young Investigators program will support 200 new awards, for a total of 950. The Request augments research training and initiation programs throughout the Foundation.

At all levels of education and research, NSF has special programs for minority institutions and minority, women and disabled students and investigators. The FY 1991 Request includes almost $94 million for these efforts, or a 48.5 percent increase over the FY 1990 target of $63.1.

In addition to existing programs to assist underrepresented groups, such as Facilitation Awards for the Handicapped, Research Improvement in Minority Institutions, and Research Opportunities for Women, the FY 1991 Request proposes to initiate:

- An Alliances for Minority Participation program to help students complete baccalaureate degrees and make a successful transition to graduate school; and
- A Faculty Recognition Awards for Women program to recognize exemplary women scientists and engineers.

CONCLUSION

By emphasizing human resource development through education and research initiation, and support for core disciplines and facilities, the Foundation's FY 1991 Request is a balanced portfolio of investment in our nation's future. It is an investment designed to nurture the close relationship between basic research and education in science and engineering and, in so doing, improve productivity and economic competitiveness.

EXPLANATION OF CARRYOVER 1989

In addition to the FY 1990 appropriation, unobligated balances totaling $38.183 million are available for obligation in FY 1990. The sources of these funds are as follows:

- The unobligated balance of $37.951 million from the FY 1989 Research and Related Activities Appropriation which consists of: $37.000 million of funds available during FY 1989 for the replacement of the NRAO telescope at Green Bank, West Virginia, which were carried over pending completion of design studies necessary prior to construction; $56 thousand of small unobligated balances in each of the research directorates; and $895 thousand of funds available in the 1989 NSF appropriation for the International Institute for Applied Systems Analysis (IIASA). These funds have been set aside in the research directorates, whose disciplinary programs would be supported by the work proposed by IIASA pending completion of the proposal review.
- The $61 thousand unobligated balance from the FY 1989 Science and Engineering Education Activities Appropriation is carried over from small unobligated balances in each of the subactivities. This balance will be used to fund the activities planned in FY 1990.

A balance of $171 thousand from the United States Antarctic Appropriation remained unobligated at the end of FY 1989. This balance will be available for operations support during FY 1990.

Crosswalk from Current Plan to FY 1990 Estimates (000)

	FY 1990 Current Plan New Obligational Authority	Carryover from FY1989	FY1990 Estimate
Biological, Behavioral and Social Sciences	$293,535	$170	$293,705
Computer and Information Science and Engineering	169,792	89	169,881
Engineering	200,221	137	200,358
Geosciences	375,006	194	375,200
Mathematical and Physical Sciences	557,006	37,314	594,320
Scientific, Technological and International Affairs	63,468	47	63,515
Science and Engineering Education	204,265	61	204,326
U.S. Antarctic Research	151,682	171	151,853

SUMMARY BUDGET INFORMATION BY SUBACTIVITY,
ACTIVITY AND APPROPRIATION: FY 1989-FY 1991 (Dollars in Thousands)

	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
RESEARCH AND RELATED ACTIVITIES					
Biological, Behavioral and Social Sciences	$281,469	$314,500	$293,535	$327,525	$33,990
Computer and Information Science and Engineering	151,838	191,200	169,792	193,250	23,458
Engineering	187,065	211,200	200,221	226,000	25,779
Geosciences	309,909	341,300	325,006	383,725	58,719
Mathematical and Physical Sciences	503,803	553,500	557,006	621,500	64,494
Research Facilities Modernization	0	0	19,690	20,000	310
Science and Technology Centers	0	20,000	0	0	0
Scientific, Technological and International Affairs	58,311	67,322	63,468	74,000	10,532
Program Development and Management	91,286	104,000	96,383	102,500	6,117
NSF Headquarters Relocation	0	0	0	5,500	5,500
Subtotal, Research and Related Activities Appro.	1,583,681	1,803,022	1,725,101	1,954,000	228,899
Carryover 1989	0	0	37,951	0	(37,951)
Total, Research and Related Activities	1,583,681	1,803,022	1,763,052	1,954,000	190,948
SCIENCE AND ENGINEERING EDUCATION ACTIVITIES APPROPRIATION					
Teacher Preparation and Enhancement	63,662	68,500	81,000	89,600	8,600
Materials Development, Research and Informal Science Education	43,986	49,000	48,000	61,500	13,500
Undergraduate Science, Engineering and Mathematics Education	27,999	30,000	34,000	50,000	16,000
Research Career Development	30,980	38,000	36,900	44,900	8,000
Studies and Program Assessment	4,500	4,500	4,365	5,000	635
Subtotal, Science and Engineering Education Appro.	171,127	190,000	204,265	251,000	46,735
Carryover 1989	0	0	61	0	(61)
Total, Science and Engineering Education	171,127	190,000	204,326	251,000	46,674
U.S. ANTARCTIC RESEARCH PROGRAM					
U.S. Antarctic Research Program	15,572	17,500	17,016	19,000	1,984
Operations Support	88,497	102,200	99,370	110,000	10,630
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704
Subtotal, Antarctic Research Program Appro.	131,069	156,000	151,682	175,000	23,318
Carryover 1989	0	0	171	0	(171)
Subtotal, Antarctic Research Program	131,069	156,000	151,853	175,000	23,147
OFFICE OF INSPECTOR GENERAL APPROPRIATION	0	0	2,560	3,000	440
SUBTOTAL, NSF APPROPRIATION	1,885,877	2,149,022	2,083,608	2,383,000	299,392
Carryover 1989	0	0	38,183	0	(38,183)
TOTAL, NSF	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY
SHOWING DOLLAR AND PERCENTAGE CHANGES: FY 1991/FY 1990 (Dollars in Thousands)

	Actual FY 1989	Request FY 1990	Current Plan FY 1990 1/	Estimate FY 1991	Difference FY 1991/1990	
					Amount	Percent
BIOLOGICAL, BEHAVIORAL & SOCIAL SCIENCES						
Molecular Biosciences	$46,703	$51,380	$48,043	$51,963	$3,920	8.2%
Cellular Biosciences	55,532	60,580	57,326	63,075	5,749	10.0%
Biotic Systems and Resources	62,815	76,010	66,704	73,385	6,681	10.0%
Behavioral and Neural Sciences	44,825	48,280	45,843	49,058	3,215	7.0%
Social and Economic Science	30,873	33,220	32,259	35,490	3,231	10.0%
Instrumentation and Resources	36,571	40,030	38,460	43,229	4,769	12.4%
Science and Technology Centers	4,150	5,000	4,900	11,325	6,425	131.1%
Total, BBS	281,469	314,500	293,535	327,525	33,990	11.6%
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING						
Computer and Computation Research	21,169	23,673	21,981	24,280	2,299	10.5%
Information Robotics and Intelligent Systems	19,136	21,637	19,980	22,880	2,900	14.5%
Microelectronic Information Processing Systems	14,977	18,952	16,609	18,870	2,261	13.6%
Advanced Scientific Computing	55,586	71,689	62,830	62,580	(250)	-0.4%
Networking and Communications Research and Infrastructure	17,608	27,133	22,190	31,290	9,100	41.0%
Cross-Disciplinary Activities	17,437	21,416	19,636	24,030	4,394	22.4%
Science and Technology Centers	5,925	6,700	6,566	9,320	2,754	41.9%
Total, CISE	151,838	191,200	169,792	193,250	23,458	13.8%
ENGINEERING						
Biological and Critical Systems	34,067	39,920	39,431	36,130	(3,301)	-8.4%
Chemical and Thermal Systems	30,979	35,912	34,179	33,140	(1,039)	-3.0%
Electrical and Communications Systems	29,872	36,040	32,922	31,810	(1,112)	-3.4%
Mechanical and Structural Systems	23,039	26,778	25,282	24,410	(872)	-3.4%
Design and Manufacturing Systems	18,056	21,850	20,695	19,770	(925)	-4.5%
Engineering Centers	40,427	50,700	47,712	55,310	7,598	15.9%
Engineering Infrastructure Development	10,625	0	0	25,430	25,430	N/A
Total, ENG.	187,065	211,200	200,221	226,000	25,779	12.9%
GEOSCIENCES						
Atmospheric Sciences	98,577	109,440	104,097	120,119	16,022	15.4%
Earth Sciences	54,222	65,160	60,106	71,531	11,425	19.0%
Ocean Sciences	145,883	152,880	147,373	171,000	23,627	16.0%
Arctic Research Program	10,284	12,820	12,450	16,650	4,200	33.7%
Science and Technology Centers	943	1,000	980	4,425	3,445	351.5%
Total, GEO	309,909	341,300	325,006	383,725	58,719	18.1%
MATHEMATICAL AND PHYSICAL SCIENCES						
Mathematical Sciences	66,019	76,046	69,118	73,720	4,602	6.7%
Astronomical Sciences	89,224	94,018	91,647	100,700	9,053	9.9%
Physics	122,284	129,998	123,831	130,230	6,399	5.2%
Chemistry	96,745	103,428	97,945	103,350	5,405	5.5%
Materials Research	115,084	135,177	116,939	123,460	6,521	5.6%
Science and Technology Centers	13,947	14,833	14,536	27,040	12,504	86.0%
Major Research Equipment	500	0	42,990	63,000	20,010	46.5%
Total, MPS	503,803	553,500	557,006	621,500	64,494	11.6%
RESEARCH FACILITIES MODERNIZATION	0	0	19,690	20,000	310	1.6%
SCIENCE AND TECHNOLOGY CENTERS	0	20,000	0	0	0	0.0%

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY
SHOWING DOLLAR AND PERCENTAGE CHANGES: FY 1991/FY 1990 (Dollars in Thousands)

	Actual FY 1989	Request FY 1990	Current Plan FY 1990 1/	Estimate FY 1991	Difference FY 1991/1990	
					Amount	Percent
SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS						
Science Resources Studies	4,252	6,000	5,313	5,990	677	12.7%
Policy Research and Analysis	852	850	843	850	7	0.8%
Research Initiation and Improvement	22,932	26,740	26,030	32,150	6,120	23.5%
Industrial Science and Technological Innovation	19,052	21,460	20,046	22,930	2,884	14.4%
International Cooperative Scientific Activities	11,223	12,272	11,236	12,080	844	7.5%
Total, STIA	58,311	67,322	63,468	74,000	10,532	16.6%
PROGRAM DEVELOPMENT AND MANAGEMENT	91,286	104,000	96,383	102,500	6,117	6.3%
NSF HEADQUARTERS RELOCATION	0	0	0	5,500	5,500	0
TOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,725,101	1,954,000	228,899	13.3%
Carryover 1989	0	0	37,951	0	(37,951)	-100.0%
TOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,763,052	1,954,000	190,948	10.8%
SCIENCE AND ENGINEERING EDUCATION						
Teacher Preparation and Enhancement	63,662	68,500	81,000	89,600	8,600	10.6%
Materials Development, Research and Informal Science Education	43,986	49,000	48,000	61,500	13,500	28.1%
Undergraduate Science, Engineering and Mathematics Education	27,999	30,000	34,000	50,000	16,000	47.1%
Research Career Development	30,980	38,000	36,900	44,900	8,000	21.7%
Studies and Program Assessment	4,500	4,500	4,365	5,000	635	14.5%
SUBTOTAL	171,127	190,000	204,265	251,000	46,735	22.9%
Carryover 1989	0	0	61	0	(61)	-100.0%
Total, SEE	171,127	190,000	204,326	251,000	46,674	22.8%
U.S. ANTARCTIC PROGRAM						
U.S. Antarctic Research Program	15,572	17,500	17,016	19,000	1,984	11.7%
Operations Support	88,497	102,200	99,370	110,000	10,630	10.7%
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704	30.3%
Subtotal	131,069	156,000	151,682	175,000	23,318	15.4%
Carryover 1989	0	0	171	0	(171)	-100.0%
Total, USAP	131,069	156,000	151,853	175,000	23,147	15.2%
OFFICE OF INSPECTOR GENERAL	0	0	2,560	3,000	440	17.2%
TOTAL, NATIONAL SCIENCE FOUNDATION	1,885,877	2,149,022	2,083,608	2,383,000	299,392	14.4%
Carryover 1989	0	0	38,183	0	(38,183)	-100.0%
TOTAL, NATIONAL SCIENCE FOUNDATION	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209	12.3%

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES					
MOLECULAR BIOSCIENCES					
Biochemistry	$13,479	$14,500	$13,843	$14,690	$847
Biophysics	14,349	15,940	14,700	15,600	900
Genetics	18,875	20,940	19,500	21,673	2,173
Total	46,703	51,380	48,043	51,963	3,920
CELLULAR BIOSCIENCES					
Cell Biology	15,771	17,368	16,106	17,233	1,127
Cellular Biochemistry	11,965	12,691	12,220	13,579	1,359
Developmental Biology	13,892	14,838	14,340	15,917	1,577
Physiological Processes	13,904	15,683	14,660	16,346	1,686
Total	55,532	60,580	57,326	63,075	5,749
BIOTIC SYSTEMS AND RESOURCES					
Ecology	9,955	12,430	10,684	11,784	1,100
Ecosystem Studies	23,478	27,330	24,400	26,881	2,481
Systematic Biology	12,719	15,920	13,720	15,020	1,300
Population Biology and Physiological Ecology	10,451	12,960	11,300	12,400	1,100
Biological Research Resources	6,212	7,370	6,600	7,300	700
Total	62,815	76,010	66,704	73,385	6,681
BEHAVIORAL AND NEURAL SCIENCES					
Anthropology	7,899	8,000	8,000	8,600	600
Language, Cognition and Social Behavior	9,643	10,200	9,600	10,300	700
Biological Basis of Behavior	11,321	12,950	12,000	13,028	1,028
Neuroscience	15,962	17,130	16,243	17,130	887
Total	44,825	48,280	45,843	49,058	3,215
SOCIAL AND ECONOMIC SCIENCE					
Economics	12,874	13,886	13,339	14,280	941
Geography	2,937	3,195	3,240	3,860	620
Sociology	3,724	4,170	3,960	4,340	380
Measurement Methods and Data Improvement	2,372	2,375	2,380	2,630	250
Political Science	3,785	3,980	3,860	4,240	380
Law and Social Sciences	1,917	2,107	2,060	2,350	290
Decision, Risk and Management Science	3,264	3,507	3,420	3,790	370
Total	30,873	33,220	32,259	35,490	3,231
INSTRUMENTATION AND RESOURCES					
Instrumentation and Instrument Development	16,593	18,100	16,000	16,600	600
Special Projects	17,728	19,430	20,000	23,979	3,979
Studies in Science and Technology	2,250	2,500	2,460	2,650	190
Total	36,571	40,030	38,460	43,229	4,769
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	4,150	5,000	4,900	11,325	6,425
TOTAL, BBS	$281,469	$314,500	$293,535	$327,525	$33,990

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING					
COMPUTER AND COMPUTATION RESEARCH					
Computer and Computation Theory	$6,425	$6,719	$6,421	$6,890	$469
Numeric and Symbolic Computation	2,829	2,951	3,330	3,990	660
Computer Systems Architecture	3,098	3,595	3,100	3,210	110
Software Systems	6,076	6,870	5,870	6,130	260
Software Engineering	2,741	3,538	3,260	4,060	800
Total	21,169	23,673	21,981	24,280	2,299
INFORMATION, ROBOTICS AND INTELLIGENT SYSTEMS					
Knowledge and Database Systems	7,680	8,213	7,750	9,120	1,370
Robotics and Machine Intelligence	6,037	6,770	6,240	6,550	310
Interactive Systems	2,660	3,387	2,660	3,050	390
Information Technology and Organizations	2,759	3,267	3,330	4,160	830
Total	19,136	21,637	19,980	22,880	2,900
MICROELECTRONIC INFORMATION PROCESSING SYSTEMS					
Design, Tools and Test	2,987	3,295	3,119	3,620	501
Microelectronic Systems Architecture	2,669	3,087	2,840	3,240	400
Circuits and Signal Processing	3,416	3,783	3,560	3,820	260
Experimental Systems	4,087	6,080	4,900	5,700	800
Systems Prototyping and Fabrication	1,818	2,707	2,190	2,490	300
Total	14,977	18,952	16,609	18,870	2,261
ADVANCED SCIENTIFIC COMPUTING					
Centers	53,793	69,028	60,210	59,590	(620)
New Technologies	1,793	2,661	2,620	2,990	370
Total	55,586	71,689	62,830	62,580	(250)
NETWORKING AND COMMUNICATIONS RESEARCH AND INFRASTRUCTURE					
NSFNET	13,590	19,632	15,960	22,040	6,080
Networking and Communications Research	4,018	7,501	6,230	9,250	3,020
Total	17,608	27,133	22,190	31,290	9,100
CROSS-DISCIPLINARY ACTIVITIES					
CISE Institutional Infrastructure	14,946	18,928	17,143	20,540	3,397
CISE Instrumentation	2,491	2,488	2,493	3,490	997
Total	17,437	21,416	19,636	24,030	4,394
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	5,925	6,700	6,566	9,320	2,754
TOTAL, CISE	$151,838	$191,200	$169,792	$193,250	$23,458

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
ENGINEERING					
BIOLOGICAL AND CRITICAL SYSTEMS					
Bioengineering and Aiding the Disabled	$11,380	$12,570	$11,325	$12,280	$955
Environmental and Ocean Systems	5,292	5,575	5,430	5,900	470
Earthquake Hazard Mitigation	14,837	15,485	14,325	15,250	925
NEHRP Funds Transferred Pursuant to P.L. 101-130	0	0	2,000	0	(2,000)
Natural and Man-Made Hazard Mitigation	2,558	2,733	2,520	2,700	180
Total	34,067	36,363	35,600	36,130	530
CHEMICAL AND THERMAL SYSTEMS					
Chemical Reaction Processes	6,736	6,722	6,600	7,000	400
Interfacial, Transport and Separations Processes	7,624	8,973	7,900	8,775	875
Thermal Systems	7,807	7,989	7,550	8,145	595
Fluid, Particulate and Hydraulic Systems	8,812	9,028	8,615	9,220	605
Total	30,979	32,712	30,665	33,140	2,475
ELECTRICAL AND COMMUNICATIONS SYSTEMS					
Quantum Electronics, Waves and Beams	7,946	8,930	7,950	8,500	550
Solid State and Microstructures	9,030	9,472	8,850	9,400	550
Communications and Computational Systems	4,857	5,508	4,850	5,450	600
Engineering Systems	6,214	6,195	6,225	6,625	400
Emerging Technologies Initiation	1,825	2,733	1,835	1,835	0
Total	29,872	32,838	29,710	31,810	2,100
MECHANICAL AND STRUCTURAL SYSTEMS					
Dynamic Systems and Control	3,179	3,361	3,130	3,350	220
Structures and Building Systems	6,655	7,178	6,620	7,100	480
Materials Engineering and Tribology	7,123	7,406	7,000	7,540	540
Solid and Geomechanics	6,082	6,449	5,950	6,420	470
Total	23,039	24,394	22,700	24,410	1,710
DESIGN AND MANUFACTURING SYSTEMS					
Operations Research and Production Systems	4,689	5,256	5,000	5,710	710
Design and Computer-Integrated Engineering	6,021	6,549	5,940	6,325	385
Manufacturing Processes and Equipment	7,346	8,098	7,350	7,735	385
Total	18,056	19,903	18,290	19,770	1,480
ENGINEERING CENTERS					
Engineering Research Centers	37,175	44,315	42,575	50,070	7,495
Industry/University Cooperative Research Centers	3,252	4,675	3,860	5,240	1,380
Total	40,427	48,990	46,435	55,310	8,875
ENGINEERING INFRASTRUCTURE DEVELOPMENT					
Engineering Education	1,700	6,000	6,000	12,000	6,000
Human Resources Development	4,222	4,630	6,525	8,930	2,405
Physical Infrastructure Development	3,260	3,520	2,470	2,500	30
Special Studies and Analyses	1,443	1,850	1,826	2,000	174
Total	10,625	16,000	16,821	25,430	8,609
TOTAL, ENGINEERING	$187,065	$211,200	$200,221	$226,000	$25,779

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
GEOSCIENCES					
ATMOSPHERIC SCIENCES					
Atmospheric Sciences Project Support	$49,914	$55,230	$53,187	$63,409	$10,222
National Center for Atmospheric Research	43,693	48,250	45,290	49,930	4,640
Upper Atmospheric Facilities	4,970	5,960	5,620	6,780	1,160
Total	98,577	109,440	104,097	120,119	16,022
EARTH SCIENCES					
Earth Sciences Project Support	36,696	42,320	39,690	46,351	6,661
NEHRP Funds Transferred Pursuant to P.L. 101-130	0	0	1,000	0	(1,000)
Instrumentation and Facilities	12,568	15,200	13,850	18,450	4,600
Continental Dynamics	4,958	7,640	5,566	6,730	1,164
Total	54,222	65,160	60,106	71,531	11,425
OCEAN SCIENCES					
Ocean Sciences Research Support	70,915	74,660	72,935	88,585	15,650
Oceanographic Centers and Facilities	43,589	45,330	42,458	47,438	4,980
Ocean Drilling Program	31,379	32,890	31,980	34,977	2,997
Total	145,883	152,880	147,373	171,000	23,627
ARCTIC RESEARCH PROGRAM					
Arctic Research Projects	9,784	12,320	11,965	16,140	4,175
Arctic Research Commission	500	500	485	510	25
Total	10,284	12,820	12,450	16,650	4,200
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	943	1,000	980	4,425	3,445
TOTAL GEOSCIENCES	$309,909	$341,300	$325,006	$383,725	$58,719

1/ Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
MATHEMATICAL AND PHYSICAL SCIENCES					
MATHEMATICAL SCIENCES					
Classical Analysis	$5,807	$6,467	$5,970	$6,220	$250
Modern Analysis	5,779	6,464	5,960	6,210	250
Geometric Analysis	5,890	7,163	6,310	6,680	370
Topology and Foundations	7,036	7,870	7,240	7,550	310
Algebra and Number Theory	9,848	11,149	10,120	10,560	440
Applied Mathematics	8,134	9,204	8,300	8,700	400
Statistics and Probability	7,264	8,209	7,440	7,810	370
Computational Mathematics	4,737	5,854	4,908	5,220	312
Special Projects	11,526	13,666	12,870	14,770	1,900
Total	66,019	76,046	69,118	73,720	4,602
ASTRONOMICAL SCIENCES					
Astronomy Project Support	28,651	31,231	30,420	31,910	1,490
National Astronomy and Ionosphere Center	6,187	6,347	6,267	11,270	5,003
National Optical Astronomy Observatories	24,321	25,230	24,620	25,770	1,150
National Radio Astronomy Observatory	30,065	31,210	30,340	31,750	1,410
Total	89,224	94,018	91,647	100,700	9,053
PHYSICS					
Elementary Particle Physics	40,114	43,434	39,831	41,330	1,499
Nuclear Sciences	41,898	44,706	42,000	43,500	1,500
Atomic, Molecular, and Optical Physics	13,868	14,421	14,300	15,400	1,100
Theoretical Physics	16,616	17,084	17,400	18,700	1,300
Gravitational Physics	9,788	10,353	10,300	11,300	1,000
Total	122,284	129,998	123,831	130,230	6,399
CHEMISTRY					
Chemical Instrumentation	8,251	8,900	8,100	8,800	700
Organic and Macromolecular Chemistry	23,882	24,968	24,520	25,290	770
Physical Chemistry	28,454	29,840	29,060	30,480	1,420
Inorganic, Bioinorganic and Organomettalic Chemistry	15,959	16,630	16,250	17,170	920
Analytical and Surface Chemistry	12,719	13,540	12,950	13,660	710
Special Projects	7,480	9,550	7,065	7,950	885
Total	96,745	103,428	97,945	103,350	5,405
MATERIALS RESEARCH					
Materials Research Project Support	64,833	69,610	66,059	69,160	3,101
Materials Research Laboratories and Groups	34,218	36,197	34,550	36,900	2,350
National Facilities and Instrumentation	16,033	17,370	16,330	17,400	1,070
Total	115,084	123,177	116,939	123,460	6,521
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	13,947	14,833	14,536	27,040	12,504
MAJOR RESEARCH EQUIPMENT					
Major Research Equipment	500	12,000	42,990	63,000	20,010
TOTAL, MPS	$503,803	$553,500	$557,006	$621,500	$64,494

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
RESEARCH FACILITIES MODERNIZATION					
Research Facilities Modernization	$0	$0	$19,690	$20,000	$310
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	0	20,000	0	0	0
SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS					
SCIENCE RESOURCES STUDIES					
Studies of Science and Engineering Resources	4,252	6,000	5,313	5,990	677
Total	4,252	6,000	5,313	5,990	677
POLICY RESEARCH AND ANALYSIS					
Policy Research and Analysis	852	850	843	850	7
Total	852	850	843	850	7
RESEARCH INITIATION AND IMPROVEMENT					
Individual & Group Support for Women and Minorities	4,211	5,950	5,682	11,550	5,868
Minority Institutional Development Support	10,630	10,790	10,548	10,800	252
EPSCoR	8,091	10,000	9,800	9,800	0
Total	22,932	26,740	26,030	32,150	6,120
INDUSTRIAL SCIENCE AND TECHNOLOGICAL INNOVATION					
Small Business Innovation Research	19,052	21,460	20,046	22,510	2,464
College and University Innovation Research	0	0	0	420	420
Total	19,052	21,460	20,046	22,930	2,884
INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES					
International Cooperative Science	11,223	12,272	11,236	12,080	844
Total	11,223	12,272	11,236	12,080	844
TOTAL, STIA	58,311	67,322	63,468	74,000	10,532
PROGRAM DEVELOPMENT AND MANAGEMENT					
Program Development and Management	91,286	104,000	96,383	102,500	6,117
NSF HEADQUARTERS RELOCATION	0	0	0	5,500	5,500
SUBTOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,725,101	1,954,000	228,899
Carryover 1989	0	0	37,951	0	(37,951)
TOTAL, RESEARCH AND RELATED ACTIVITIES	$1,583,681	$1,803,022	$1,763,052	$1,954,000	$190,948

1/ Current Plan amounts exclude carryover unubligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
SCIENCE AND ENGINEERING EDUCATION					
TEACHER PREPARATION AND ENHANCEMENT					
Science and Mathematics Education Networks	$9,000	$10,000	$16,000	$23,000	$7,000
Teacher Enhancement	45,127	46,000	53,100	54,200	1,100
Presidential Awards for Excellence in Science and Mathematics Teaching	1,816	2,500	2,900	2,900	0
Teacher Preparation	7,719	10,000	9,000	9,500	500
Total	63,662	68,500	81,000	89,600	8,600
MATERIALS DEVELOPMENT, RESEARCH AND INFORMAL SCIENCE EDUCATION					
Applications of Advanced Technologies	5,986	6,500	6,300	6,500	200
Informal Science Education	15,000	16,000	15,700	19,000	3,300
Instructional Materials Development	18,500	21,500	21,200	31,000	9,800
Research in Teaching and Learning	4,500	5,000	4,800	5,000	200
Total	43,986	49,000	48,000	61,500	13,500
UNDERGRADUATE SCIENCE, ENGINEERING AND MATHEMATICS EDUCATION					
Instrumentation & Laboratory Improvement	16,000	16,000	15,800	23,000	7,200
Faculty Enhancement	3,000	3,000	2,900	4,000	1,100
Career Access Opportunities in S&T for Women, Minorities & the Disabled	5,000	7,000	11,300	15,000	3,700
Course and Curriculum	3,999	4,000	4,000	8,000	4,000
Total	27,999	30,000	34,000	50,000	16,000
RESEARCH CAREER DEVELOPMENT					
Graduate Fellowships	21,580	28,000	25,400	30,500	5,100
Minority Graduate Fellowships	2,400	3,000	4,500	5,400	900
Young Scholars	7,000	7,000	7,000	9,000	2,000
Total	30,980	38,000	36,900	44,900	8,000
STUDIES AND PROGRAM ASSESSMENT					
Studies and Analyses	4,500	4,500	4,365	5,000	635
Total	4,500	4,500	4,365	5,000	635
SUBTOTAL, SEE	171,127	190,000	204,265	251,000	46,735
Carryover 1989	0	0	61	0	(61)
TOTAL, SEE	$171,127	$190,000	$204,326	$251,000	$46,674

1/ Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
U.S. ANTARCTIC PROGRAM					
U.S. ANTARCTIC RESEARCH PROGRAM					
U.S. Antarctic Research Program	$15,572	$17,500	$17,016	$19,000	$1,984
Total	15,572	17,500	17,016	19,000	1,984
OPERATIONS SUPPORT					
Science Support	19,300	26,000	24,280	28,000	3,720
Operations and Maintenance	69,197	76,200	75,090	82,000	6,910
Total	88,497	102,200	99,370	110,000	10,630
MAJOR CONSTRUCTION AND PROCUREMENT					
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704
Total	27,000	36,300	35,296	46,000	10,704
SUBTOTAL, USAP	131,069	156,000	151,682	175,000	23,318
Carryover 1989	0	0	171	0	(171)
TOTAL, USAP	131,069	156,000	151,853	175,000	23,147
OFFICE OF INSPECTOR GENERAL					
Office of Inspector General	0	0	2,560	3,000	440
SUBTOTAL, NSF	1,885,877	2,149,022	2,083,608	2,383,000	299,392
Carryover 1989	0	0	38,183	0	(38,183)
TOTAL, NSF	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209

1/ Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

RESEARCH AND RELATED ACTIVITIES APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	$1,583,681
FY 1990:	
Increases:	
Biological, Behavioral and Social Sciences	12,236
Computer and Information Science and Engineering	18,043
Engineering	13,293
Geosciences	15,291
Mathematical and Physical Sciences	90,517
Scientific, Technological and International Affairs	5,204
Program Development and Management	5,097
Subtotal	159,681
FY 1990 Obligated Level	1,743,362
FY 1991:	
Increases:	
Biological, Behavioral and Social Sciences	33,820
Computer and Information Science and Engineering	23,369
Engineering	25,642
Geosciences	58,525
Mathematical and Physical Sciences	27,180
Research Facilities Modernization	20,000
Scientific, Technological and International Affairs	10,485
Program Development and Management	6,117
NSF Headquarters Relocation	5,500
Subtotal	210,638
Fy 1991 Obligated Level	1,954,000

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

ACADEMIC RESEARCH FACILITIES APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	0
FY 1990: **Increase**:	
Academic Research Facilities	19,690
Subtotal	19,690
FY 1990 Obligated Level	19,690
FY 1991: **Decrease**:	
Academic Research Facilities	(19,690)
Subtotal	(19,690)
FY1991 Obligated Level	0

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

SCIENCE AND ENGINEERING EDUCATION APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	$171,127
FY 1990:	
Increases:	
Teacher Preparation and Enhancement	17,399
Materials Development, Research and Informal Science Education	4,014
Undergraduate Science, Engineering and Mathematics Education	6,001
Research Career Development	5,920
Subtotal	33,334
Decrease:	
Studies & Program Assessment	(135)
FY 1990 Obligated Level	204,326
FY 1991:	
Increases:	
Teacher Preparation and Enhancement	8,539
Materials Development, Research and Informal Science Education	13,500
Undergraduate Science, Engineering and Mathematics Education	16,000
Research Career Development	8,000
Studies & Program Assesment	635
Subtotal	46,674
FY 1991 Obligated Level	251,000

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

U.S. ANTARCTIC ACTIVITIES APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	$131,069
FY 1990:	
Increases:	
U.S. Antarctic Research Program	1,444
Major Construction and Procurement	8,296
Subtotal	9,740
Decrease:	
Antarctic Operations	(68,685)
FY 1990 Obligated Level	72,124
FY 1991:	
Increases:	
U.S. Antarctic Research Program	1,984
Antarctic Operations	90,188
Major Construction and Procurement	10,704
Subtotal	102,876
FY 1991 Obligated Level	175,000

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

U.S. ANTARCTIC LOGISTICAL SUPPORT APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	0
FY 1990:	
Increase:	
U.S. Antarctic Logistical Support	79,729
Subtotal	79,729
FY 1990 Obligated Level	79,729
FY 1991:	
Decreases:	
U.S. Antarctic Logistical Support	(79,729)
Subtotal	(79,729)
FY 1991 Obligated Level	0

ANALYSIS OF CHANGES IN OBLIGATION LEVELS:FY 1989-FY 1991

OFFICE OF INSPECTOR GENERAL APPROPRIATION

(DOLLARS IN THOUSANDS)

	Obligations
FY 1989 Obligated Level	0
FY 1990:	
Increase:	
Office of Inspector General	2,560
Subtotal	2,560
FY 1990 Obligated Level	2,560
FY 1991:	
Increase:	
Office of Inspector General	440
Subtotal	440
FY 1991 Obligated Level	3,000

PERCENTAGE DISTRIBUTION OF TOTAL OBLIGATIONS: FY 1989-FY 1991

	ACTUAL FY 1989	REQUEST FY1990	CURRENT PLAN FY1990	ESTIMATE FY1991
RESEARCH AND RELATED ACTIVITIES				
Biological, Behavioral and Social Sciences	14.9%	14.6%	14.1%	13.7%
Computer and Information Science and Engineering	8.1	8.9	8.1	8.1
Engineering	9.9	9.8	9.6	9.5
Geosciences	16.4	15.9	15.6	16.1
Mathematical and Physical Sciences	26.7	25.8	26.7	26.1
Research Facilities Modernization	0.0	0.0	0.9	0.8
Science and Technology Centers	0.0	0.9	0.0	0.0
Scientific, Technological and International Affairs	3.1	3.1	3.0	3.1
Program Development and Management	4.8	4.8	4.6	4.3
NSF Headquarters Relocation	0.0	0.0	0.0	0.2
Subtotal, Research and Related Activities	84.0%	83.8%	82.8%	82.0%
SCIENCE AND ENGINEERING EDUCATION ACTIVITIES				
Teacher Preparation and Enhancement	3.4%	3.2%	3.9%	3.8%
Materials Development, Research and Informal Science Education	2.3	2.3	2.3	2.6
Undergraduate Science, Engineering and Mathematics Education	1.5	1.4	1.6	2.1
Research Career Development	1.6	1.8	1.8	1.9
Studies and Program Assessment	0.2	0.2	0.2	0.2
Subtotal, Science and Engineering Education	9.0%	8.9%	9.8%	10.6%
U.S. ANTARCTIC PROGRAM				
U.S. Antarctic Research Program	0.8%	0.8%	0.8%	0.8%
Operations Support	4.7	4.8	4.8	4.6
Major Construction and Procurement	1.4	1.7	1.7	1.9
Subtotal, U.S. Antarctic Program	7.0	7.3	7.3	7.3
OFFICE OF INSPECTOR GENERAL	0.0	0.0	0.1	0.1
TOTAL, NSF	100.0%	100.0%	100.0%	100.0%

SUMMARY OF OBLIGATIONS BY MAJOR OBJECT CLASSIFICATION (Dollars in Thousands)

	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990	ESTIMATE FY 1991	DIFFERENCE
Research and Related Activities					
Personnel Compensation	$54,878	$57,973	$55,629	$59,500	$3,871
Personnel Benefits	8,365	8,566	8,971	9,500	529
Travel and Transportation of Persons	2,921	3,750	3,400	3,600	200
Transportation of Things	322	230	350	400	50
Rents and Communication	10,628	11,895	11,635	12,080	445
Printing and Reproduction	660	820	820	820	0
Other Contractual Services					0
Program Contracts	72,088	159,352	94,409	110,880	16,471
Program Development & Management Contracts	8,807	12,281	9,761	10,320	559
Supplies and Materials	560	905	890	900	10
Equipment	4,140	7,550	4,897	5,350	453
Grants, Subsidies, Contributions					0
Program Grants	1,420,296	1,539,670	1,552,570	1,740,620	188,050
Program Development and Management Grants	16	30	30	30	0
Subtotal, Research and Related Activities	1,583,681	1,803,022	1,743,362	1,954,000	210,638
Science and Engineering Education Activities					
Other Contractual Services					
Program Contracts	4,168	4,000	2,000	2,000	0
Program Grants	166,959	186,000	202,326	249,000	46,674
Subtotal, Science and Engineering Education	171,127	190,000	204,326	251,000	46,674
U.S. Antarctic Logistical Support Activities					
Other Contractual Services					
Program Contracts	0	0	79,729	0	(79,729)
Subtotal, U.S. Antarctic Logistical Support	0	0	79,729	0	(79,729)
United States Antarctic Program Activities					
Other Contractual Services					
Program Contracts	115,294	138,000	43,624	149,000	105,376
Program Grants	15,775	18,000	28,500	26,000	(2,500)
Subtotal, United States Antarctic Program	131,069	156,000	72,124	175,000	102,876
Office of Inspector General					
Personnel Compensation	0	0	1,210	1,360	150
Personnel Benefits	0	0	182	204	22
Travel and Transportation of Persons	0	0	45	50	5
Rents and Communication	0	0	0	205	205
Printing and Reproduction	0	0	1	1	0
Other Contractual Services	0	0	1,076	1,134	58
Supplies and Materials	0	0	6	6	0
Equipment	0	0	40	40	0
Subtotal, Office of Inspector General	0	0	2,560	3,000	440
Academic Research Facilities					
Other Contractual Services					
Program Grants	0	0	19,690	0	(19,690)
Subtotal, Academic Research Facilities	0	0	19,690	0	(19,690)
TOTAL NSF	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209

NSF APPROPRIATION LANGUAGE

RESEARCH AND RELATED ACTIVITIES

For necessary expenses in carrying out the purposes of the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), and the Act to establish a National Medal of Science (42 U.S.C. 1880-1881); services as authorized by 5 U.S.C. 3109; maintenance and operation of aircraft and purchase of flight services for research support; acquisition of aircraft; hire of passenger motor vehicles; not to exceed $6,000 for official reception and representation expenses; uniforms or allowances therefor, as authorized by law (5 U.S.C 5901-5902); rental of conference rooms in the District of Columbia; and reimbursement of the General Services Administration for security guard services; [$1,715,000,000] *$1,954,000,000,* to remain available until September 30,[1991 of which $900,000,000 shall not be available for obligation until April 1, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided*, That of the funds appropriated in this Act, or from funds appropriated previously to the Foundation, not more than $97,900,000 shall be available for program development and management in fiscal year 1990:] *1992. Provided* [further], That contracts may be entered into under the program development and management [limitation] *activity* in fiscal year [1990] 1991 for maintenance and operation of facilities, and for other services, to be provided during the next fiscal year: [*Provided further*, That none of the funds appropriated in this Act may be used directly or through grants, contracts or other award mechanisms, for agreements executed after enactment of this Act, to pay or to provide reimbursement for the Federal portion of the salary of any individual functioning as a Federal employee at more than the daily equivalent of the maximum rate paid for ES-6 for assignments to Senior Executive Service positions, unless specifically authorized by law: Provided further, That notwithstanding the preceding proviso, none of the funds appropriated in this Act may be used to pay the salary of any individual functioning as a Federal employee, or any other individual, through a grant or grants at a rate in excess of $95,000 per year: *Provided further*, That of the funds appropriated in this Act, $900,000 shall be available only for the International Institute for Applied Systems Analysis, and that, notwithstanding any other provision of law, the Director may choose not to obligate these funds for that purpose:] *Provided further*, That receipts for scientific support services and materials furnished by the National Research Centers and other National Science Foundation supported research facilities may be credited to this appropriation[: *Provided further*, That to the extent that the amount appropriated is less than the total amount authorized to be appropriated for included program activities, all amounts, including floors and ceilings, specified in the authorizing Act for those program activities or their subactivities shall be reduced proportionally]. (*Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.*)

NSF APPROPRIATION LANGUAGE, continued

[ACADEMIC RESEARCH FACILITIES]

[For necessary expenses in carrying out an academic research facilities program pursuant to the purposes of the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), including services as authorized by 5 U.S.C 3109 and rental of conference rooms in the District of Columbia, $20,000,000, to remain available until September 20, 1991: *Provided*, That funds made available under this heading shall not be available for obligation until September 1, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change. (*Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.*)]

UNITED STATES ANTARCTIC PROGRAM ACTIVITIES

For necessary expenses in carrying out the research and operational support for the United States Antarctic Program pursuant to the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875); maintenance and operation of aircraft and purchase of flight services for research and operations support; *improvement of environmental practices and enhancements of safety*; maintenance and operation of research ships and charter or lease of ships for research and operations support; hire of passenger motor vehicles; not to exceed $2,500 for official reception and representation expenses; [$74,000,000,] *$175,000,000*, to remain available until expended: *Provided*, That receipts for support services and materials provided for non-Federal activities may be credited to this appropriation[: *Provided further*, That no funds in this account shall be used for the purchase of aircraft other than ones transferred from other Federal agencies: *Provided further*, That no funds in this or any other Act shall be used to acquire or lease a research vessel with ice-breaking capability built by a shipyard located in a foreign country if such a vessel of United States origin can be obtained at a cost no more than 50 percentum above that of the least expensive technically acceptable foreign vessel bid: *Provided further*, That, in determining the cost of such a vessel, such cost be increased by the amount of any subsidies or financing provided by a foreign government (or instrumentality thereof) to such vessel's construction: *Provided further*, That if the vessel contracted for pursuant to the foregoing is not available for the 1989-1990 austral summer Antarctic season, a vessel of any origin may be leased for a period of not to exceed 120 days for that season and each season thereafter until delivery of the new vessel: *Provided further*, That the preceding three provisos shall not apply to appropriated funds used for the lease of the vessel POLAR DUKE, nor for procurements covered by the GATT Agreement on Government Procurement: *Provided further*, That the vessel contracted for pursuant to the foregoing shall be of United States registry]. (*Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.*)

NSF APPROPRIATION LANGUAGE, continued

[UNITED STATES ANTARCTIC LOGISTICAL SUPPORT ACTIVITIES]

[For necessary expenses in reimbursing Federal agencies for logistical and other related activities for the United States Antarctic Program pursuant to the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875); maintenance, and operation of aircraft and purchase of flight services for research and operations support; improvement of environmental practices and enhancements of safety; maintenance and operation of research ships and charter or lease of ships for research and operations support; improvement of environmental practices and enhancement of safety; hire of passenger motor vehicles; not to exceed $82,000,000, to remain available until expended: *Provided*, That funds made available under this heading shall not become available for obligation until September 30, 1990, and pursuant to section 202(b) of the Balanced Budget and Emergency Deficit Control Reaffirmation Act of 1987, this action is a necessary (but secondary) result of a significant policy change: *Provided further*, That receipts for support services and materials provided for non-Federal activities may be credited to this appropriation. *(Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.)*]

NSF APPROPRIATION LANGUAGE, continued

SCIENCE *AND ENGINEERING* EDUCATION ACTIVITIES

For necessary expenses in carrying out science and engineering education programs and activities pursuant to the purposes of the National Science Foundation Act of 1950, as amended (42 U.S.C. 1861-1875), including services as authorized by 5 U.S.C. 3109 and rental of conference rooms in the District of Columbia, [$210,000,000,] *$251,000,000*, to remain available until September 30, [1991: *Provided*, That to the extent that the amount of this appropriation is less than the total amount authorized to be appropriated for included **program activities**, all amounts, including floors and ceilings, specified in the authorizing Act for those program activities or their subactivities shall be reduced proportionally.] *1992. (Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.)*

NSF APPROPRIATION LANGUAGE, continued

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the provisions of the Inspector General Act of 1978, as amended, [$2,600,000,] *$3,000,000*, to remain available until September 30, [1991] *1992*. *(Departments of Veteran Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990.)*

RESEARCH AND RELATED ACTIVITIES $1,954,000,000

SUMMARY OF REQUEST

The FY 1991 Request for Research and Related Activities (R&RA) is $1,954.00 million, an increase of $228.90 million, or 13.3 percent, over the FY 1990 Current Plan of $1,725.10 million.

(Millions of Dollars)

Activity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY1991 Request
Biological, Behavioral and Social Sciences	$281.47	$314.50	$293.54	$327.53
Computer and Information Science and Engineering	151.84	191.20	169.79	193.25
Engineering	187.06	211.20	200.22	226.00
Geosciences	309.91	341.30	325.01	383.73
Mathematical and Physical Sciences	503.80	553.50	557.01	621.50
Research Facilities Modernization	N/A	N/A	19.69	20.00
Science and Technology Centers	0	20.00	0	0
Scientific, Technological and International Affairs ..	58.31	67.32	63.47	74.00
Program Development and Management	91.29	104.00	96.38	102.50
NSF Headquarters Relocation	N/A	N/A	N/A	5.50
Research and Related Activities	$1,583.68	$1,803.02	$1,725.10	$1,954.00

NSF ROLE

R&RA supports basic scientific and engineering research, training and education through competitive grants primarily made to universities and colleges. Support includes awards to individual investigators, groups of investigators, science and technology research centers, facilities, and awards that support the infrastructure of science and engineering, like travel, conferences, symposia, instrumentation, and education and human resource development.

The **Biological, Behavioral and Social Sciences** (BBS) Activity promotes the scientific understanding of biological and social phenomena. Research is supported across the spectrum, from the fundamental molecules of living organisms to the complex interactions of human beings and societal organizations. Support to individual investigators is the largest component, comprising more than 60 percent of the total.

Research in the **Computer and Information Sciences and Engineering** (CISE) Activity is directed at information processing in the broadest sense of the term, ranging from fundamental theory to systems engineering. In addition, significant attention is devoted to advanced computer and communication facilities and services for the general U.S. scientific and engineering research and higher education community.

Research supported by the **Engineering** (ENG) Activity promotes the progress of engineering and technology in the U.S. to ensure that the Nation stays in the forefront of engineering research and education and responds to future technological opportunities and needs.

The **Geosciences** (GEO) Activity supports research to advance knowledge of the natural environment of the earth, including its atmosphere, oceans, and interior. This research includes most of the Foundation's contribution to the U.S. Global Change Research Program.

Research in the **Mathematical and Physical Sciences** (MPS) Activity is directed at increasing understanding of natural laws and phenomena. It includes research in mathematics, astronomy, physics, chemistry, and materials science.

The **Research Facilities Modernization** (RFM) Activity provides competitively awarded grants for the repair, renovation, or, in exceptional cases, replacement of facilities used for research and research training at academic and non-profit institutions. RFM responds directly to the legislative mandate to carry out the Academic Research Facilities Modernization Program.

The **Scientific, Technological, and International Affairs** (STIA) Activity facilitates international scientific cooperation; provides policy-oriented data, information and analysis; and supports human resource development activities that strengthen the Nation's scientific and engineering research base.

The **Program Development and Management** (PD&M) Activity provides for the operation, support, management, and direction of all NSF programs and activities and includes necessary funds to develop, manage, and coordinate these program activities. Funds for support of the Office of the Inspector General are requested separately.

The **NSF Headquarters Relocation** Activity provides for significant non-recurring costs associated with the relocation of NSF headquarters now planned for 1992.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Activity	FY1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Biological, Behavioral and Social Sciences	$281.47	$314.50	$293.54	$-20.96	-6.7%
Computer and Information Science and Engineering	151.84	191.20	169.79	-21.41	-11.2
Engineering	187.06	211.20	200.22	-10.98	-5.2
Geosciences	309.91	341.30	325.01	-16.29	-4.8
Mathematical and Physical Sciences	503.80	553.50	557.01	3.51	0.6
Research Facilities Modernization	N/A	N/A	19.69	19.69	N/A
Science and Technology Centers	0.00	20.00	0.00	-20.00	N/A
Scientific, Technological and International Affairs	58.31	67.32	63.47	-3.85	-5.7
Program Development and Management	91.29	104.00	96.38	-7.62	-7.3
NSF Headquarters Relocation	N/A	N/A	N/A	N/A	N/A
Research and Related Activities	$1,583.68	$1,803.02	$1,725.10	$-77.92	-4.3%

The FY 1990 Current Plan is $1,725.10 million, which is a decrease of $77.92 million, or -4.3 percent, from the FY 1990 Budget Request of $1,803.02 million.

There were several steps in the FY 1990 appropriations process, including the across-the-board reductions specified in Section 517 of Public Law 101-144, and the further reductions mandated by the Budget and Reconciliation Act of 1989 (Public Law 101-239).

Final Current Plan allocations:

- deferred the new set of Science and Technology Centers (STCs) until FY 1991;
- protected Global Change research, the Experimental Program to Stimulate Competitive Research (EPSCOR), and women and minorities programs at or near requested levels;
- included funds in the MPS Activity for the Green Bank telescope provided for in Public Law 101-45, which accounts for much of the increase in that Activity;
- partially restored reductions that would otherwise have occurred in astronomy in the MPS Activity in order to protect research and field operations; and
- assigned funds appropriated in Public Law 101-130 for earthquake-related research in response to the Loma Prieta earthquake to the ENG Activity ($2.00 million) and the GEO Activity ($1.00 million).

All other Activities, Subactivities, and programs were proportionately adjusted, retaining the same general priorities as existed in the request, but at considerably reduced levels.

These reductions in resources are directly reflected in the number and scope of research and educational projects that will be supported from each part of the Account. NSF will make fewer awards in FY 1990 than projected in the Request, in order to increase the average award size. Since the largest fraction of NSF Research and Related Activities expenditures support the human component at the core of the research and education enterprise, the current plan reductions translate to support for 4700 fewer scientists, engineers, and graduate and undergraduate students.

(numbers of people supported in R&RA)

	FY1990 Request	FY1990 Current Plan
Senior Scientists	17,700	16,800
Postdoctorals	4,000	3,600
Graduate Students	16,300	14,400
Undergraduates	9,000	7,500
Total	47,000	42,300

These and other impacts are described in each Activitiy section of the budget.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Activity	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Biological, Behavioral and Social Sciences	$293.54	$327.53	$33.99	11.6%
Computer and Information Science and Engineering	169.79	193.25	23.46	13.8
Engineering	200.22	226.00	25.78	12.9
Geosciences	325.01	383.73	58.72	18.1
Mathematical and Physical Sciences	557.01	621.50	64.49	11.6
Research Facilities Modernization	19.69	20.00	0.31	1.6
Science and Technology Centers	0.00	0.00	0.00	N/A
Scientific, Technological and International Affairs	63.47	74.00	10.53	16.6
Program Development and Management	96.38	102.50	6.12	6.3
NSF Headquarters Relocation	N/A	5.50	5.50	N/A
Research and Related Activities	$1,725.10	$1,954.00	$228.90	13.3%

R&RA increases by $228.90 million, or 13.3 percent, over the FY1990 Current Plan to total $1,954.00 million.

In **Biological, Behavioral, and Social Sciences** a major research initiative in plant sciences will support the genome project to map and sequence a model plant system, providing the human resource base necessary to advance research in this important area. Support for individual and group projects will be increased in critical areas of global environmental change and computational biology.

BBS will expand its broad-based initiative on the design and development of shareable biological databases. Understanding biological processes and the ability to capitalize on rapid developments in biological sciences are dependent on the capability to collect, manage, and manipulate large-scale databases.

Increased focus on human resources and education is required to sustain and enhance the recent progress in the life sciences. Approximately $37.00 million will be available for such activities. Support will focus on research initiation awards for new investigators, research training awards, and postdoctoral fellowships.

The **Computer and Information Science and Engineering** Activity will emphasize software information technology to improve research for high performance computing, collaborative work, and experimental application-specific computing systems.

As in FY 1990, CISE will increase activity in advanced scientific computing and networking. The request includes an increase of $7.76 million for four centers to:

- upgrade hardware and software systems;
- undertake an integrated program to improve service offerings; and

- perform new research on computational science software and methods.

NSFNET will increase by $9.00 million to better serve the basic research and higher education community through technical upgrades to improve services and security, transition to international protocol standards, and advanced research on very high performance networks and applications.

The CISE disciplines pay special attention not only to undergraduate education but also to human resources development. CISE will provide a $3.00 million increase for undergraduate programs, and will increase the number of research initiation awards and Presidential Young Investigators.

The FY 1991 **Engineering** request provides for:

- increased research in high priority areas such as downstream biochemical processing, solid state and microstructures, optical high-speed communications, manufacturing and design and hazards mitigation;
- an increase for Earthquake-related research from $14.32 million to $15.25 million (excluding the transfer of funds in 1990 pursuant to P.L.101-130); and
- a special research thrust on the processing of advanced materials, including polymers, superconductors, microstructures, composites, and biomaterials.

The Engineering Research Centers program will increase by $7.50 million to $50.10 million in FY 1991. In FY 1991 no additional centers are planned. The increase will allow ENG to address the concern, expressed by the recent National Academy of Engineering study, that current average annual funding for centers is not adequate to achieve the original ERC program objectives.

A new Subactivity, Engineering Infrastructure Development, focuses attention and resources on programs aimed at revitalizing engineering undergraduate education and the infrastructure of the engineering disciplines. Undergraduate engineering programs will increase from $12.40 million to $22.20 million in FY 1991 to:

- develop model undergraduate engineering courses and fund Engineering Education Coalitions that focus on comprehensive curriculum reform;
- provide for increased participation of women and minorities in undergraduate research and education;
- provide for Research Experiences for Undergraduates sites; and
- fund instructional instrumentation and research equipment.

A principal part of the **Geosciences** Activity is the Global Geosciences Program, an interrelated set of programs that seek to understand, and ultimately predict future changes in the earth's environment including the polar regions. The Global Geosciences Program is a major contributor to the government-wide U.S. Global Change Research Program (USGCRP). NSF's contribution to the USGCRP will total $103 million within the BBS and GEO Activities as well as the U.S. Antarctic Program.

In GEO, funding for the Global Geosciences Program will almost double to $85 million, with emphases on:

- climate and hydrologic cycles;

- biogeochemical and ecosystems dynamics;
- earth systems history; and
- establishment and management of databases.

Support for the requisite facilities for conducting laboratory studies, field experiments, and modeling activities will increase to support the National Center for Atmospheric Research, the academic research fleet, instrumentation for the earth sciences, and the Ocean Drilling Program.

The GEO Activity will increase support for programs to improve research opportunities for young investigators and to attract graduate and undergraduate students and minorities to the geosciences. In all, support for the development of human resources increases to $20.28 million.

Major research equipment and instrumentation needs across all **Mathematical and Physical Sciences** disciplines are highlighted. Increases are planned for research in special areas of opportunity such as design of special materials, environmental chemistry, and the interaction of mathematics with other disciplines.

Two new construction projects are planned — a gravity wave observatory and 8-meter optical/infrared telescopes. These major undertakings will contribute to maintaining U.S. leadership in gravitational physics and ground-based astronomy and at the same time take advantage of opportunities for international cooperation. In cooperation with NASA, an upgrade of the Arecibo Observatory will be started. Support will continue for the National High Magnetic Field Laboratory.

Nearly $46.00 million will be provided in FY 1991 to strengthen human resources, which will emphasize:

- undergraduate curriculum development, particularly at the introductory level for physics, chemistry and mathematics;
- programs to increase the participation of underrepresented groups; and
- support for new investigators.

The **Research Facilities Modernization** Activity will provide another $20.00 million in FY1991 funds, which together with the 1990 funding provides almost $40.00 milion for awards made as a result of the first competition.

In **Scientific, Technological, and International Affairs,** awards under the Small Business Innovation Research (SBIR) Program will provide $22.51 million to small R&D and product-based companies to perform research possibly leading to more rapid commercialization of new high technology products and processes. A new program, College and University Innovation Research (CUIR) will test the SBIR concept in an academic environment.

In International Cooperative Scientific Activities, special attention will be on support of activities related to reopening of scientific communications with Poland, Czechoslovakia, and the U.S.S.R.

Research Initiation and Improvement programs increase over $6.00 million to $32.15 million in order to:

- bolster the Research Careers for Minority Scholars program which is aimed at encouraging talented undergraduate students to begin and continue studies leading to careers in science and engineering;

- continue the Experimental Program to Stimulate Competitive Research (EPSCoR) which assists states in building local resources for science and engineering; and
- hold another competition for two to three new Minority Research Centers of Excellence (MRCE's).

Intramural analyses and other data collection activities will increase to almost $6.00 million to continue the redesign of the Scientific and Technical Personnel Data System (STPDS). This redesign effort represents a commitment by NSF to implement an enhanced system over the next decade.

The **Program Development and Management** Activity accounts for only 4.3 percent of the Foundation's total FY 1991 request. It provides funds for staff salaries and other operating expenses necessary to manage and administer the Foundation's program responsibilities, but excludes funds for the Office of the Inspector General which are requested separately.

The increase in PD&M includes:

- $4.40 million for personnel compensation and benefits necessary to cover the cost of the government-wide pay raise and support 1,225 FTE;
- $0.51 million for information systems to continue the conversion of management systems to the mainframe as well as the replacement cycle for personal computer workstations;
- $0.96 million to maintain current levels of essential contract services and building rental and maintenance; and $0.25 million to fund increased levels of support services for travel, training, and printing.

The **NSF Headquarters Relocation** Activity is established to accommodate the consolidation of the NSF's two office facilities into a single facility in the Washington Metropolitan Area. In addition to accommodating staff levels needed to support the Foundation's programs, the new facility will:

- provide expanded conferencing facilities for advisory committee and panel review meetings;
- meet NSF's rapidly increasing needs for electronic cabling and networking;
- allow greater flexibility to accommodate organizational changes; and
- improve the overall working environment.

Plans are on schedule for the lease award and site selection to occur in the spring of 1990, and it will take about two years to complete construction. The move to the new building is scheduled to begin in the summer of 1992.

DISTRIBUTED AND SPECIAL FOCUS PROGRAMS

The Foundation has developed several programs to strengthen the research infrastructure and develop human resources for science and engineering. All science and engineering research and education activities provide support under these umbrella efforts. Management of the programs is distributed, and closely coupled with the ongoing functions and responsibilities of each Activity. In this way, concerns are addressed in the context of discipline-specific problems and needs.

Science and Technology Centers (STCs)

In FY 1991, $25 million is requested to fund the second class of STCs. Proposals were received in the fall of 1989, and are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for this set of awards are distributed in the four research Activities, based upon proposals in each set of disciplines, as follows:

(Millions of Dollars)

STC Subactivity	**FY1991 Estimate**
Biological, Behavioral and Social Science	$6.325
Computer and Information Science and Engineering	2.750
Geosciences	3.425
Mathematical and Physical Sciences	12.500
Total, STCs	$25.000

Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

Undergraduate Research and Education

The FY 1991 Request includes $134.23 million for undergraduate research and education, $43.76 million (48.4 percent) over the FY 1990 target. These funds are distributed between the R&RA Account and the SEE Account in order to distribute responsibility for undergraduate activities to all research disciplines.

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
By Mode of Support:		
Students	$29.57	$38.88
Faculty	19.29	20.39
Instrumentation and Laboratory Improvement	22.28	26.33
Course and Curriculum	16.33	35.47
Other	3.00	13.16
Total, Undergraduate Programs	$90.47	$134.23
By Account:		
Research and Related Activities	$56.47	$ 84.23
Science and Engineering Education	$34.00	$ 50.00

The undergraduate plan is a comprehensive NSF-wide approach to the problems of undergraduate education and is based on the needs of individual disciplines as well as broader educational issues. The undergraduate initiative, which began in FY 1987, includes support for student research, faculty enhancement, course and curriculum development, and instructional instrumentation.

Highlights of the FY 1991 Request include:

- $35 million for course and curriculum development, more than twice the amount estimated for FY 1990;
- $26 million for instrumentation and laboratory improvement, an 18.2 percent increase over FY 1990, for awards to institutions including two- and four-year colleges and research universities; and
- $14 million for research experiences for undergraduates to provide hands-on research experience to undergraduate students.

Underrepresented Groups

Within overall NSF efforts to broaden participation in science and engineering, underrepresented groups receive additional attention. Focus is on women, minorities, and the disabled. This effort involves not only distributed programs, such as Minority Research Initiation (MRI) and Research Opportunities for Women (ROW), but also targeted programs, such as Research Improvement in Minority Institutions (RIMI), Minority Research Centers of Excellence (MRCE), Research Careers for Minority Scholars (RCMS) and Visiting Professorships for Women (VPW) in the R&RA Account and Career Access Opportunities in the SEE Acccount.

The FY 1991 Request includes $94.08 million for this set of programs, $30.98 million (49.1 percent) over the FY 1990 target.

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
By Support of Mode:		
Students	$9.94	$17.80
Faculty	8.85	15.07
Institutions	23.18	39.13
Other	21.13	22.08
Total, Underrepresented Groups	$63.10	$94.08
By Account:		
Research and Related Activities	$45.95	$71.53
Science and Engineering Education	$17.15	$22.55

Two new programs are established in the R&RA Account:

- Faculty Awards for Women will recognize and support outstanding faculty women in science and engineering. These awards will be given annually to 100 young women scientists and engineers nominated by their institutions.
- The Alliances for Minority Participation program will encourage undergraduate minority students to complete their baccalaureate degrees and to pursue graduate studies in science and engineering. Projects will address problems such as retention, support, and inadequate student preparation, and will emphasize comprehensive approaches to these problems with strong local involvement in project design. In FY 1991, approximately ten institutions will receive awards through this program.

BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES $327,525,000

SUMMARY OF REQUEST

The FY 1991 Request for Biological, Behavioral and Social Sciences (BBS) Activity is $327.53 million, an increase of $33.99 million, or 11.6 percent, over the FY 1990 Current Plan of $293.54 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Molecular Biosciences	$46.70	$51.38	$48.04	$51.96
Cellular Biosciences	55.53	60.58	57.33	63.08
Biotic Systems and Resources	62.82	76.01	66.70	73.39
Behavioral and Neural Sciences	44.83	48.28	45.84	49.06
Social and Economic Science	30.87	33.22	32.26	35.49
Instrumentation and Resources	36.57	40.03	38.46	43.23
Science and Technology Centers	4.15	5.00	4.90	11.33
Total, Activity	$281.47	$314.50	$293.54	$327.53

NSF ROLE

The goal of the Biological, Behavioral and Social Sciences (BBS) Activity is to promote progress in the life sciences. This is achieved by supporting research in major fields of life science; providing instrumentation, facilities and opportunities for multidisciplinary collaboration; and developing trained scientific personnel.

BBS research programs:

- Increase understanding of the ways chemical and physical events at the molecular and subcellular levels underlie fundamental life processes;
- Provide insights into the interactions of biological systems and their environments;
- Increase knowledge of the structures and functions of the nervous system and the biological and cultural factors that influence the behavior of humans and other animals;
- Explain how various social and economic systems are organized and operate.

Many BBS research areas are multidisciplinary and cut across Subactivity lines. For example, fundamental research in plant biology includes studies of the molecular structure and function of plant cells, supported by both the Cellular and the Molecular Biosciences Subactivities. It also includes research on plant distribution, and plant-plant and plant-environment interactions, supported by Biotic Systems and Resources. NSF provides over 50 percent of federal support in this area of basic research.

BBS support in the life sciences contributes to the overall progress across many topical areas. For example, research related to biological diversity spans all BBS disciplines, including such critical areas as systematic biology and ecology. Conservation and restoration practices derive from research in these subdisciplines as well as population biology and physiological processes. BBS also supports research at the interface of the biological sciences and the social sciences where cross-disciplinary knowledge ultimately contributes to development of public policies.

Two continuing emphases make NSF unique among the federal agencies that support the biological, behavioral and social sciences:

- Highly innovative research projects that have the potential for significant advances in the field. Thirty percent of total resources go to new investigators in new lines of research.
- Significant infrastructure and research resources development and maintenance. Another 22 percent of resources go to personnel, instrumentation, facilities, and shareable datasets.

NSF's role differs somewhat by subdiscipline and with the proportion of total federal support the Foundation provides:

- Across the biological sciences, the Foundation's role is heavily catalytic, emphasizing new and highly innovative approaches to forefront research. BBS provides unique support for personnel training in specialized subfields and major instrument development and acquisition. While NIH provides the largest share of federal funds, their research support is mainly related to specific diseases.
- In environmental biology, NSF provides 75 percent of all federal support. Here, BBS balances support for highly productive lines of ongoing research with critical infrastructure development and maintenance projects (e.g., field stations refurbishment), and investments in new and highly innovative research areas.
- In the behavioral and social sciences, the Foundation's role is particularly important, accounting for nearly one-third of all federal support. In anthropology, NSF is virtually the sole source of academically-based research. NSF's focus in the behavioral and social sciences is highly theoretically-based and quantitative.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Molecular Biosciences	$46.70	$51.38	$48.04	$-3.34	-6.5%
Cellular Biosciences	55.53	60.58	57.33	-3.25	-5.4
Biotic Systems and Resources	62.82	76.01	66.70	-9.31	-12.2
Behavioral and Neural Sciences	44.83	48.28	45.84	-2.44	-5.1
Social and Economic Science	30.87	33.22	32.26	-0.96	-2.9
Instrumentation and Resources	36.57	40.03	38.46	-1.57	-3.9
Science and Technology Centers	4.15	5.00	4.90	-0.10	-2.0
Total, Activity	$281.47	$314.50	$293.54	$-20.96	-6.7%

The FY 1990 Current Plan is $293.54 million, which is a decrease of $20.96 million, or 6.7 percent, from the FY 1990 Budget Request of $314.5 million. This decrease represents the Activity's share of Congressionally mandated budget reductions and is spread among all the Subactivities.

Within the FY 1990 allocation, human resources priorities receive absolute increments, but at a lower rate of growth than requested. Other priorities are addressed at nearly the requested level. These priorities include research areas fundamental to understanding and conserving biodiversity, plant biology, support for multidisciplinary training and development of shared database resources.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Molecular Biosciences	$48.04	$51.96	$3.92	8.2%
Cellular Biosciences	57.33	63.08	5.75	10.0
Biotic Systems and Resources	66.70	73.39	6.69	10.0
Behavioral and Neural Science	45.84	49.06	3.22	7.0
Social and Economic Science	32.26	35.49	3.23	10.0
Instrumentation and Resources	38.46	43.23	4.77	12.4
Science and Technology Centers	4.90	11.33	6.42	131.0
Total, Activity	$293.54	$327.53	$33.99	11.6%

The BBS Activity is increased by $33.99 million or 11.58 percent over the FY 1990 Current Plan to a total of $327.53 million. The FY 1991 request incorporates the Foundation's central budget themes.

RESEARCH AND FACILITIES:

Support for research and facilities comprises 88 percent or $289 million of the BBS Activity. The FY 1991 request provides nearly a $22 million increase, over a base of $268 million for a total of $289 million.

Research and facility support is important due to the increasingly cross-disciplinary nature involved in continuing the progress of the life sciences. This support provides the environment for research in which the research community can undertake complex experiments requiring significant resources, and enhance the ability to link education and training to forefront research.

- Plant Sciences ($4.47 million): to initiate support for the genome project to map and sequence *Arabidopsis* as a model plant system using a functional approach. FY 1991 support will begin to establish the human resource base and genetic stock resources necessary to advance research in this important area. Support will include research initiation awards for young investigators and interdisciplinary training at the undergraduate, graduate and postdoctoral levels.
- Global Environmental Change ($5.25 million): to advance understanding of the effects of global change on the biosphere on which life depends. Research support will focus on ecological responses and the human dimensions of global change. Support will include expanded opportunities to enhance skills in specialized techniques such as computer modeling, Geographic Information System (GIS), and supercomputer applications.
- Computational Biology and Databases ($1.53 million): to focus on the need for database development, standardization, integration, management and manipulation of shareable

databases across the breadth of the biological sciences. Support will focus on instrumentation related to the major initiatives: plant sciences and global environmental change.

- Average award sizes will increase ($2.00 million) to support increased costs of advanced instrumentation and support graduate students.
- Development of computing and information software capability in the ecological sciences at the Long-Term Ecological Research Sites ($0.75 million) will support large-scale studies in areas such as global change.
- In addition, this increase includes $1.0 million for the continued development of the Minority Research Center of Excellence at Meharry Medical College. This center conducts research in the areas of cellular and molecular biology. Responsibility for this center is transferred to the Cellular Biosciences Subactivity from the Research Inititation and Improvement Subactivity of the Scientific, Technological and International Affairs Activity.
- This increase includes $6.42 million to establish additional science and technology centers to continue providing opportunities for complex multidisciplinary research.

EDUCATION AND HUMAN RESOURCES:

Sustaining and enhancing progress in the life sciences requires constant attention to developing the future pool of human resources. This will include ensuring opportunities from the pre- to post-graduate levels: undergraduates, graduates, postdoctoral scientists, as well as mid-career level training in modern techniques. The FY 1991 request provides a $12 million increase over the base of $26 million for these activities.

- BBS will continue to support the Minority Postdoctoral Research Fellowship Program begun in FY 1990 ($1.50 million), support of minority students and supplements to minority students awarded honorable mention as NSF Fellows.
- BBS will maintain its human resources support of development and training in research grants and in specialized activities such as postdoctoral fellowships, research initiation awards for new investigators, and research training awards.
- Research Training Groups ($1.25 million): to enhance support for a new program initiated in FY 1990 to support new or significantly enhance multidisciplinary training programs at Ph.D. granting institutions.
- Undergraduate activities will be sustained at FY 1990 levels and BBS will participate fully in course and curriculum development and the new alliances for the Minority Participation Program ($4.80 million) and the NSF Faculty Awards for Women ($1.20 million).
- BBS will support the multiagency education and training program related to multidisclipinary research on global change ($3.10 million)

MOLECULAR BIOSCIENCES $51,963,000

SUMMARY OF REQUEST

The FY 1991 Request for the Molecular Biosciences (DMB) Subactivity is $51.96 million, an increase of $3.92 million, or 8.2 percent, over the FY 1990 Current Plan of $48.04 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Biochemistry	$13.48	$14.50	$13.84	$14.69
Biophysics	14.35	15.94	14.70	15.60
Genetics	18.88	20.94	19.50	21.67
Total, Subactivity	$46.70	$51.38	$48.04	$51.96

SCIENTIFIC OVERVIEW

Research in the Molecular Biosciences increases fundamental understanding of the chemical, genetic and physical processes underlying biological phenomena. This Subactivity emphasizes:

- research leading to advances in plant molecular biology,
- all aspects of research in molecular genetics, such as the organization, recombination, regulation, and transmission of heritable information in organisms ranging from microbes to animals, and
- interdisciplinary approaches to molecular biological problems involving chemical, mathematical and physical techniques.

The molecular biosciences are a vital contributor to biotechnology. The study of the structure, function and regulation of genes and how they may be moved from one biological system to another, using the techniques of recombinant DNA, provides valuable understanding of genes. Such studies provide the foundation for new production methods for biochemicals. Similarly, research in plant molecular biology advances understanding of mechanisms underlying photosynthesis and nitrogen fixation, and disease resistance, and thus provides the future basis for improved agriculture.

A particularly noteworthy research achievement is reflected in the NSF-supported research of Dr. Sidney Altman of Yale University. Dr. Altman was awarded the 1989 Nobel Prize for his research on the catalytic activity of RNA. Although controversial at the outset, Dr. Altman's remarkable findings have stimulated reexamination of the roles of both RNA and protein. There is now precedent for the suggestion that RNA, even in the absence of protein, represents the earliest, self-replicating, biochemical system.

NSF has encouraged geneticists trained in microbial and animal genetics to direct their attention to some of the challenging scientific opportunities in plant genetics. Geneticists, Dr. Ronald W. Davis of Stanford University, Dr. Gerald R. Fink of the Whitehead Institute and Dr. Elliot M. Meyerowitz of California Institute of Technology, have shown that a weed, *Arabidopsis*, has great potential as a model plant system. Efforts to map the relatively simple genome of this plant and to integrate biochemical, genetic and functional studies, facilitating our broad understanding of many plants, is a result of their contributions.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Biochemistry	$13.48	$14.50	$13.84	$-0.66	-4.6%
Biophysics	14.35	15.94	14.70	-1.24	-7.8
Genetics	18.88	20.94	19.50	-1.44	-6.9
Total, Subactivity	$46.70	$51.38	$48.04	$-3.34	-6.5%

The FY 1990 Current Plan is $48.04 million, which is a decrease of $3.34 million, or 6.5 percent, from the FY 1990 Request of $51.38 million. This decrease represents the Subactivity's share of Congressionally mandated budget reductions and is spread among all the program elements. The Subactivity's increase of $1.34 million, or 2.9 percent over FY 1989 is primarily directed to high priority projects in genetics and biophysics.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Biochemistry	$13.84	$14.69	$0.85	6.1%
Biophysics	14.70	15.60	0.90	6.1
Genetics	19.50	21.67	2.17	11.1
Total, Subactivity	$48.04	$51.96	$3.92	8.2%

The Molecular Biosciences Subactivity will continue several emphases from prior years and will increase support by $3.92 million in specific areas, including:

- Plant molecular biology, especially mapping and genetic sequence projects for *Arabidopsis* as a model plant system ($1.50 million) supported by the Genetics program element;
- Efforts to understand the molecular and genetic basis of biodiversity ($0.40 million);
- Elaboration of molecular structure of important biological molecules, such as proteins, using the complex techniques of nuclear magnetic resonance and x-ray diffraction supported by the Biophysics program element.

Support for undergraduate activities in the molecular biosciences will continue to be provided to increase both numbers and quality of undergraduate biology students.

CELLULAR BIOSCIENCES $63,075,000

SUMMARY OF REQUEST

The FY 1991 Request for the Cellular Biosciences (DCB) Subactivity is $63.08 million, an increase of $5.75 million, or 10.0 percent, over the FY 1990 Current Plan of $57.33 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Cell Biology	$15.77	$17.37	$16.11	$17.23
Cellular Biochemistry	11.97	12.69	12.22	13.58
Developmental Biology	13.89	14.84	14.34	15.92
Physiological Processes	13.90	15.68	14.66	16.35
Total, Subactivity	$55.53	$60.58	$57.33	$63.08

SCIENTIFIC OVERVIEW

Research in the Cellular Biosciences elucidates the mechanisms by which all organisms--animals, plants and microorganisms--grow, develop, reproduce and function. The emphasis is on experimental studies to examine how life processes are initiated, regulated and integrated from the level of genes to cells, organs and organisms.

The power of current technologies of molecular biology, particularly the use of recombinant DNA and monoclonal antibodies, for identification and isolation of genes and gene products now constitutes the leading edge of research in this area.

A continuing major emphasis is the genetics and cellular biology of plant systems where new fundamental information will have potential applications both in agriculture and biotechnology. The use of a diversity of organisms as biological models is encouraged. There is a rich array of relatively understudied organisms that offer useful, and often unique, systems for investigation of important problems and for exploitation by industrial biotechnology.

The cellular biosciences involve several active areas with significant potential to unify cellular biological disciplines with allied fields, to link molecular biology with biology of organisms, and to explore biodiversity through cellular life processes.

One such area is the molecular identification and characterization of hormone receptors in plant cells. Dr. Terri Lomax, a former NSF Plant Postdoctoral Fellow and current grantee at Oregon

State University, has identified a protein in plant cells that binds to the hormone auxin and appears to function as the hormone receptor. For the first time, this identification of the auxin receptor makes possible the elucidation in plants of the molecular events by which a hormonal signal is transduced into physiological effects on growth and development.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Cell Biology	$15.77	$17.37	$16.11	$-1.26	-7.3%
Cellular Biochemistry	11.97	12.69	12.22	-0.47	-3.7
Developmental Biology	13.89	14.84	14.34	-0.50	-3.4
Physiological Processes	13.90	15.68	14.66	-1.02	-6.5
Total, Subactivity	$55.53	$60.58	$57.33	$-3.25	-5.4%

The FY 1990 Current Plan is $57.33 million, which is a decrease of $3.25 million, or 5.4 percent, from the FY 1990 Request of $60.58 million. This decrease represents the Subactivity's share of Congressionally mandated budget reductions and is spread among all the program elements. The Subactivity's increase of $1.8 million, or 3.2 percent over FY 1989 will emphasize multidisciplinary research in plant systems and biodiversity.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Cell Biology	$16.11	$17.23	$1.12	7.0%
Cellular Biochemistry	12.22	13.58	1.36	11.1
Developmental Biology	14.34	15.92	1.58	11.0
Physiological Processes	14.66	16.35	1.69	11.5
Total, Subactivity	$57.33	$63.08	$5.75	10.0%

The Cellular Biosciences will focus support on the continued development of biotechnology as well as fundamental research on metabolism, reproduction, development, growth and physiological function in cells and organisms. Support will be strengthened ($2.55 million) for research in:

- Elucidating the biochemical, cellular, and physiological processes in microbes and plants that contribute to changes in the global environment;
- Advancing the understanding of reproduction, growth, and defense mechanisms applicable to preserving and managing biodiversity supported by the Physiological Processes program element;
- Cellular, developmental, and physiological biology of plants, especially higher plants, using biotechnological techniques to address fundamental questions;
- Identification, isolation, characterization and regulation of genes important in the development of organisms;
- Mechanisms by which cells of plants and animals receive signals, process the information biochemically, and respond by releasing other signal molecules or by changing their patterns of gene expression supported by the Cell Biology program element.

A highly trained human resource base is essential for maintaining the present and future needs. These needs are so critical that in addition to an increase of $1.65 million, base funds will be invested in:

- Multidisciplinary postdoctoral training and startup research funding in plant biology, and supplemental funding for grantees to learn contemporary techniques.
- Special supplements for undergraduate and graduate students and postdoctoral researchers to increase participation of under-represented minorities.
- Additional Presidential Young Investigator awards, and career advancement awards for women.

BIOTIC SYSTEMS AND RESOURCES $73,385,000

SUMMARY OF REQUEST

The FY 1991 Request for the Biotic Systems and Resources (BSR) Subactivity is $73.39 million, an increase of $6.69 million, or 10.0 percent, over the FY 1990 Current Plan of $66.70 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Ecology	$9.96	$12.43	$10.68	$11.79
Ecosystem Studies	23.48	27.33	24.40	26.88
Systematic Biology	12.72	15.92	13.72	15.02
Population Biology and Physiological Ecology	10.45	12.96	11.30	12.40
Biological Research Resources	6.21	7.37	6.60	7.30
Total, Subactivity	$62.82	$76.01	$66.70	$73.39

SCIENTIFIC OVERVIEW

Research in Biotic Systems and Resources seeks to increase understanding of the interrelationships of organisms as they exist in nature. Studies of ecological relationships examine those processes linking together plants, animals, microorganisms, and the nonliving parts of their ecosystems—soil, air and water. Because the processes respond to changes in climatic variables and in turn influence atmosphere composition, this knowledge is important to understanding global change.

Scientists also seek to determine the basic hereditary interrelationships of organisms, both living and extinct, to trace their organic histories and establish schemes for their classification.

Research supported by this Subactivity provides the scientific framework within which problems of biological diversity and the conservation of natural resources, as well as land use management, can be addressed.

Ecological relationships are examined at several levels, from smallest organism to the global ecosystem:

- Microbial community ecology is currently a topic of emphasis. In part this examines interactions of soil microbes with plant roots and soil-living invertebrate animals.

- Increasing attention is being directed to ecological relationships undergoing environmental changes.
- Biospheric-level studies are focusing on remote sensing to analyze large-scale changes on biogeochemistry--the role of living organisms in the cycling of nutrient elements (such as carbon, nitrogen and sulfur) in soil, water and the atmosphere.

Systematic and population biology seek to determine trait similarities within and among groups of plants, animals, and microorganisms. Research using a variety of newer molecular and mathematical techniques is revising and challenging many long-standing ideas. Current interest in the nature and genetic structure of microbial populations builds upon similar studies of the biological diversity of both plants and animals that seek to understand the linkage between genetic makeup and environmental adaptability.

Biodiversity inventories are currently in a phase of rapid scaling-up to achieve the goal of globally shared taxonomic resources: well-curated specimens in natural history collections, preserved DNA and tissue samples, and networked computer databases on species and their habitats linked to Geographic Information Systems. Examples include the Flora of North America and Flora Mesoamericana projects. These projects will provide complete computerized inventories of the plants of the covered regions.

Biodiversity projects also contain significant training components: Dr. Daniel Janzen, University of Pennsylvania, has mobilized an international effort to train Costa Ricans in the techniques of inventory preparation and analysis. This is an example of imaginative and effective use of local citizens in the stewardship of biological resources. Costa Rica is an example of how conservation of biological resources can be successful when based on enlightened policies and creative use of government and local resources.

Support in this Subactivity is also provided for the development and maintenance of biological research resources important to researchers in biotic systems, such as systematic collections and controlled environmental laboratories.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Changes Amount	Changes Percent
Ecology	$9.96	$12.43	$10.68	$-1.75	-14.1%
Ecosystem Studies	23.48	27.33	24.40	-2.93	-10.7
Systematic Biology	12.72	15.92	13.72	-2.20	-13.8
Population Biology and Physiological Ecology	10.45	12.96	11.30	-1.66	-12.8
Biological Research Resources	6.21	7.37	6.60	-0.77	-10.4
Total, Subactivity	$62.82	$76.01	$66.70	$-9.31	-12.2%

The FY 1990 Current Plan is $66.70 million, which is a decrease of $9.31 million, or 12.2 percent, from the 1990 request of $76.01 million. This decrease represents the Subactivity's share of Congressionally mandated budget reductions and is spread among all the program elements. The Subactivity's increase of $3.88 million, or 6.2 percent over FY 1989, is directed to all program elements to support their involvement in the high-priority areas of biodiversity and biological databases.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Changes Amount	Changes Percent
Ecology	$10.68	$11.79	$1.11	10.4%
Ecosystem Studies	24.40	26.88	2.48	10.2
Systematic Biology	13.72	15.02	1.30	9.5
Population Biology and Physiological Ecology	11.30	12.40	1.10	9.7
Biological Research Resources	6.60	7.30	0.70	10.6
Total, Subactivity	$66.70	$73.39	$6.69	10.0%

The Biotic Systems and Resources Subactivity will continue to stress:

- Molecular techniques for determining phylogenetic and genetic relationships among organisms supported by the Systematic Biology program element;

- Microbial ecology, especially as it relates to the growth and reproduction of higher plants and to the degradation of environmental toxins supported by the Ecology program element;
- Curation of natural history collections necessitated by increased studies of world-wide biological diversity; and
- Long-Term Ecological Research Sites (LTERs), including completion of wide-area networking and development of cross-site databases ($0.75 million).

Emphasis will be placed on studies of the ecological effects of global environmental change ($1.60 million), including:

- Biogenic emissions of greenhouse gases and their effects on other ecosystem properties supported by the Ecosystem Studies program element;
- Responses of whole communities and their component species to various components of climate change , using ground-based and remote sensing;
- Expansion of the directorate-wide competition in conservation and restoration biology, begun in FY 1990; and
- Inventories of the biota of key environments, such as tropical, marine and soil habitats supported by the Systematic Biology program element.

As part of the computational biology and database initiatives, an additional $0.50 million will be used for integrative projects such as:

- Modeling regional and global ecosystem responses to climate change;
- Producing Geographic Information Systems that allow the study of changes in biotic composition and range through historical and geological time; and
- Completing computerization of U.S. collections of natural history specimens, focusing initially on vertebrates and higher plants supported by the Biological Research Resources program element.

Significant educational components are required to meet current and future needs for additional scientists, especially women and minorities. In addition to enhancing activities for graduate students (dissertation improvement awards) and postdoctoral scientists (mid-career and new-Ph.D. fellowships, Presidential Young Investigator awards), this Subactivity will participate in introductory and advanced training in the use of important tools (mathematical modeling, Geographic Information Systems) for global change and biodiversity studies.

BEHAVIORAL AND NEURAL SCIENCES 49,058,000

SUMMARY OF REQUEST

The FY 1991 Request for the Behavioral and Neural Sciences (BNS) Subactivity is $49.06 million, an increase of $3.22 million, or 7.0 percent, over the FY 1990 Current Plan of $45.84 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY1990 Current Plan	FY 1991 Request
Anthropology	$7.90	$8.00	$8.00	$8.60
Language, Cognition, and Social Behavior	9.64	10.20	9.60	10.30
Biological Basis of Behavior	11.32	12.95	12.00	13.03
Neuroscience	15.96	17.13	16.24	17.13
Total, Subactivity	$44.83	$48.28	$45.84	$49.06

SCIENTIFIC OVERVIEW

Research in the Behavioral and Neural Sciences advances understanding of the biological, environmental, and cultural factors that underlie the behavior of humans and animals. Explicit emphasis is given to nervous system structure and function. Serving as a bridge between the biological and the social sciences, the Subactivity supports research requiring a wide variety of techniques at levels ranging from the molecular to the cultural.

Research on the nervous system seeks to understand nerve cell action, the growth and development of the nervous system, how sensory stimuli are detected and integrated in the nervous system, and the underlying anatomical, physiological, and biochemical aspects of nervous system function. The roles of the nervous system and its mechanisms of physiological control (neuroendocrine system) in behavior, especially learning and memory, receive special attention.

The excitement of current research in the neurosciences is exemplified by the work of Richard Scheller, a Presidential Young Investigator at Stanford University, and the 1989 winner of the Alan T. Waterman Award. Dr. Scheller received the award for his work leading to the development of recombinant DNA technologies, and for his current research which has illuminated cellular and molecular mechanisms used to regulate animal behavior.

Research in language, cognition, and social behavior increases understanding of:

- how humans acquire, store, retrieve, and use information
- the general properties of language and how it is acquired and used
- complex behavioral interactions of people including behavioral development from childhood through adulthood.

Research by Daniel Wegner of Trinity University has shown that suppressed thoughts can have a variety of unwanted side-effects and may form an underlying cause of rebound, whereby a previously suppressed thought takes on almost obsessive qualities. His work is focused on the social psychological processes that underlie thought suppression, and the means of offsetting its effects.

Close ties are developing among cognitive science, information science, computer science and the neurosciences. Such collaborations offer major opportunities for scientific advancement.

Anthropology seeks to discover the laws or regularities underlying differences and similarities among human societies. NSF supports research on contemporary and ancient cultures, human physical diversity, the origin of humans, and the interaction between biological and social characteristics of humans.

NSF also provides support to preserve and increase accessibility to major anthropological research collections in museums, and maintains a special competition to support the development and utilization of new archaeometric (chemical and physical) techniques to increase understanding of past cultures through analyses of their material remains.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY1990 Current Plan	Changes	
				Amount	Percent
Anthropology	$7.90	$8.00	$8.00	$0.00	0.0%
Language, Cognition, and Social Behavior	9.64	10.20	9.60	-0.60	-5.9
Biological Basis of Behavior	11.32	12.95	12.00	-0.95	-7.3
Neuroscience	15.96	17.13	16.24	-0.89	-5.2
Total, Subactivity	$44.83	$48.28	$45.84	$-2.44	-5.1%

The FY 1990 Current Plan is $45.84 million, which is a decrease of $2.44 million, or 5.1 percent, from the FY 1990 Request of $48.28 million. This decrease represents the Subactivity's share of Congressionally mandated reductions. Of the Subactivity's increase of $1.01 million, or 2.3 percent over FY 1989, nearly 60 percent is directed to research in anthropology and the biological basis of behavior to support multidisclipinary projects related to biodiversity.

FY 1991 BUDGET REQUEST

(Millions of Dollar)

Program Element	FY 1990 Current Plan	FY 1991 Request	Changes	
			Amount	Percent
Anthropology	$8.00	$8.60	$0.60	7.5%
Language, Cognition, and Social Behavior	9.60	10.30	0.70	7.3
Biological Basis of Behavior	12.00	13.03	1.03	8.6
Neuroscience	16.24	17.13	0.89	5.5
Total, Subactivity	$45.84	$49.06	$3.22	7.0%

The Behavioral and Neural Sciences Subactivity will continue to emphasize research related to biodiversity, including conservation and restoration biology of endangered animal species, and in the neurobiology of learning and memory.

The requested increase ($600,000) in Anthropology will allow for increased use of molecular technologies in physical anthropology, especially in projects relating to biological diversity.

In Language, Cognition, and Social Behavior ($700,000) increased support will be provided for experimental studies of the biological underpinnings of language and cognition, and the psychophysiology of social behavior.

The most substantial increase ($1.03 million) will support additional research on the biological basis of behavior particularly, research on animal behavior related to biodiversity, biochemical events that underlie the processes of learning and memory, and hormonal influences on the brain.

The neurosciences ($890,000) will increase support in the rapidly growing area of computational neuroscience, especially computer simulation and modeling of neurons and neural networks as they relate to behavioral functions, including vision, audition, speech and motor movements.

In all areas of human resource needs increases will be directed to:

- supporting new investigators;
- increasing graduate and post-doctoral students; and
- providing hands-on research experiences for undergraduate students, especially women and minorities.

SOCIAL AND ECONOMIC SCIENCE $35,490,000

SUMMARY OF REQUEST

The FY 1991 Request for the Social and Economic Science (SES) Subactivity is $35.49 million, an increase of $3.23 million, or 10.0 percent, over the FY 1990 Current Plan of $32.26 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Economics	$12.87	$13.89	$13.34	$14.28
Geography	2.94	3.19	3.24	3.86
Sociology	3.72	4.17	3.96	4.34
Measurement Methods and Data Improvement	2.37	2.38	2.38	2.63
Political Science	3.79	3.98	3.86	4.24
Law and Social Science	1.92	2.11	2.06	2.35
Decision, Risk and Management Science	3.26	3.50	3.42	3.79
Total, Subactivity	$30.87	$33.22	$32.26	$35.49

SCIENTIFIC OVERVIEW

The Social and Economic Science Subactivity supports disciplinary and interdisciplinary research on human social behavior and social organizations and systems. The scope of this research ranges from studies of market behavior and business decision making, risk assessment and analysis, and to studies of the productivity and structural organization of science and technology. The Subactivity also maintains major collections of high quality social science data and supports research on social measurement and statistical methods of social and economic data analysis.

Projects supported include basic research; measurement and methodological research; and research resources, such as large scale databases. The NSF role in these areas is not duplicated elsewhere.

Social and Economic Science programs seek to extend the data available for research by improving the scientific utility of federal statistical data and the availability of social science research data.

The Social and Economic Science Subactivity supports the National Center for Geographic Information and Analysis (NCGIA) to conduct research on the theory, methods, and techniques of analysis using Geographic Information Systems (GISs). The NCGIA is a consortium of scientists and engineers at the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine at Orono.

The NCGIA research initiatives are inquiries into the accuracy of spatial information, development of measures of data uncertainty and confidence of products of GIS analysis. The development of GISs and the advancement of methods of analyses related to this new technology enhance the capabilities of social and economic scientists, stimulate inquiries in the biological, atmospheric, and earth sciences, and provide an integral tool for research on the human and natural processes hastening global environmental change.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Economics	$12.87	$13.89	$13.34	$-0.55	-4.0%
Geography	2.94	3.19	3.24	0.05	1.6
Sociology	3.72	4.17	3.96	-0.21	-5.0
Measurement Methods and Data Improvement	2.37	2.38	2.38	0.00	0.0
Political Science	3.79	3.98	3.86	-0.12	-3.0
Law and Social Science	1.92	2.11	2.06	-0.05	-2.4
Decision, Risk and Management Science	3.26	3.50	3.42	-0.08	-2.3
Total, Subactivity	$30.87	$33.22	$32.26	$-0.96	-2.9%

The FY 1990 Current Plan is $32.26 million, which is a decrease of $0.96 million, or 2.9 percent, from the FY 1990 Request of $33.22. This decrease represents the Subactivity's share of Congressionally mandated budget reductions. The Subactivity's increase of $1.39 million, or 4.5 percent over FY 1989, is directed to begin research on the human dimensions of global environmental change; and to geography and regional science for support of the National Center for Geographic Information and Analysis.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Economics	$13.34	$14.28	$0.94	7.0%
Geography	3.24	3.86	0.62	19.1
Sociology	3.96	4.34	0.38	9.6
Measurement Methods and Data Improvement	2.38	2.63	0.25	10.5
Political Science	3.86	4.24	0.38	9.8
Law and Social Science	2.06	2.35	0.29	14.1
Decision, Risk and Management Science	3.42	3.79	0.37	10.8
Total, Subactivity	$32.26	$35.49	$3.23	10.0%

Major new emphasis ($2.50 million) will be placed on:

- Research and data development on the human dimensions of global environmental change. Research will focus on human interactions with physical and biological processes including anthrogenic causes of global environmental change supported by both the Economics and Geography program elements. It will also include studies of the effects of regulation, economic and commodity markets, and population growth and distribution on global change. In Law and Social Sciences support will be provided for research on methodological problems in creating comparable cross-national data bases on environmentally significant activities.

The Social and Economic Science Subactivity will continue to emphasize:

- Research to improve our knowledge of technological and non-technological factors in economic competitiveness, including industrial organization, productivity and efficiency, effects of regulatory changes, international political economy, savings behavior, and labor force changes.
- Multi-user research resources, including both large-scale data bases such as the Panel Study on Income Dynamics, the General Social Survey, and the National Election Studies, and special purpose data collection on such topics as financial transactions, political participation, and domestic policy spending. In addition, support is continued for the National Center for Geographical Information and Analysis.

Human resource development activities will emphasize support for dissertation research resources and research experiences for undergraduates. Support will continue for research on women's careers in science and technology.

INSTRUMENTATION AND RESOURCES $43,229,000

SUMMARY OF REQUEST

The FY 1991 Request for the Instrumentation and Resources (DIR) Subactivity is $43.23 million, an increase of $4.77 million, or 12.4 percent, over the FY 1990 Current Plan of $38.46 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Instrumentation and Instrument Development	$16.59	$18.10	$16.00	$16.60
Special Projects	17.73	19.43	20.00	23.98
Studies in Science, Technology and Society	2.25	2.50	2.46	2.65
Total, Subactivity	$36.57	$40.03	$38.46	$43.23

SCIENTIFIC OVERVIEW

The Subactivity for Instrumentation and Resources provides centralized management of funding for most major scientific resources within the BBS Activity. With the increasing importance of resources and instrumentation to major advancement within a field, centralized support ensures a balanced provision of essential resources to all sciences. Computers play a significant role in contemporary research across all disciplines in the BBS Activity and continued efforts are required in providing powerful new computational equipment.

The Subactivity supports:

- the acquisition of major, specialized instruments for use by groups of investigators for research resources such as
  - genetic stock centers,
  - terrestrial field stations and marine laboratories, and
  - for new databases for the biological, behavioral and social sciences;
- studies of the history of science and technology and of ethics and values in relation to science; and

- development of important new methodology, of computer software, and of equipment that will increase the accuracy, range or sensitivity of research observations.

The breadth of the impact of physical methods and instrumentation on contemporary biology is shown by the work of Stuart Lindsay, Arizona State, who obtained the first high resolution Scanning Tunneling Microscopy (STM) images of hydrated DNA. The pitch or coiling of the DNA, known from X-ray crystallography, is reflected in these hydrated micrographs. This contrasts previous studies by STM and conventional Electron Microscopy of dehydrated specimens. The hydration layer of water has been known to be an important aspect of the structure of the helix. The STM should improve our understanding of the natural structure of cells and cellular organelles because water is generally important for biological structure. The STM is particularly promising for physical mapping of segments of chromosomes.

Modern biological research, especially in genetic mapping, relies increasingly on access to shared databases. Mary Berlyn, Yale University, has developed an electronic database that provides instant access to a "knowledge base" on genetic properties of *E. coli*. The database includes information on the different strains held in the *E. coli* Stock Center collection, their genetic properties, and also the gene map which indicates the location of the genes on the bacterial chromosome. Establishing this prototype database is an important first step toward linking diverse types of genetic data.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Instrumentation and Instrument Development	$16.59	$18.10	$16.00	$-2.10	-11.6%
Special Projects	17.73	19.43	20.00	0.57	2.9
Studies in Science, Technology and Society	2.25	2.50	2.46	-0.04	-1.6
Total, Subactivity	$36.57	$40.03	$38.46	$-1.57	-3.9%

The FY 1990 Current Plan is $38.46 million which is a decrease of $1.57 million, or 3.9 percent, from the FY 1990 Request of $40.03 million. This decrease represents the Subactivity's share of Congressionally mandated budget reductions. The Subactivity's increase of $1.89 million, or 5.2 percent over FY 1989 provides for initiation of research training group awards to provide training in the use of sophisticated techniques across the BBS disciplines.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Instrumentation and Instrument Development	$16.00	$16.60	$0.60	3.8%
Special Projects	20.00	23.98	3.98	19.9
Studies in Science, Technology and Society	2.46	2.65	0.19	7.7
Total, Subactivity	$38.46	$43.23	$4.77	12.4%

The Instrumentation and Resources Subactivity will continue to emphasize support for advanced instrumentation and sophisticated techniques as well as opportunities for advanced training. Examples of support include:

- Marine and terrestrial field stations refurbishment in support of their role in providing research environments for the biological science community;
- Collaborative efforts in the development of techniques and instrumentation for optical microscopy which aim at examining the implications of cellular structure and dynamics for the function of cells in culture and in the nervous system;
- Development of instrumentation, including computer software, required for contemporary work in the biological, behavioral and social sciences.

The Instrumentation and Resources Subactivity has a major role in support of the biological database initiative. An additional $1.03 million, will be used to augment the following activities:

- Access to computers and development of specialized computer applications across the biological sciences include: long term ecological research, museum collections, stock centers, and research involving macromolecular sequence information.

Additional support ($1.25 million) will be provided to continue the program initiated in FY 1990 to provide training opportunities in use of sophisticated techniques in all disciplines supported by this Activity.

Science and Technology Centers .... $ 11,325,000

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $11.33 million, an increase of $6.43 million, or 131.0 percent, over the FY 1990 Current Plan of $4.9 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$4.15	$5.00	$4.90	$11.33

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

Of the eleven centers funded in February 1989, two are in the BBS Activity, and these investments have already achieved impressive results. For example:

- The Center for Microbial Ecology at Michigan State University is devoted to the basic understanding of microorganisms and their function in natural and human-made habitats. Basic research of microbial ecology has many potential applications such as, improving groundwater quality, hazardous waster disposal, plant pest control, recycling of nutrients, fermentation, and other industrial processes.
- The Center for Development of an Integrated Protein and Nucleic Acid Biotechnology at the California Institute of Technology is focusing on the development of new instrumentation, methodology, and automated techniques necessary for contemporary basic and applied biological research, such as sequencing proteins using very small quantities of

material and sequencing DNA without the use of radioisotopes. These research efforts will impact on all of biology - from the immediate applications to the genome projects, to the new biotechnological products of the future.

CHANGES BETWEEN FY1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Science and Technology Centers	$4.15	$5.00	$4.90	$-0.10	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and the mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Science and Technology Centers	$4.90	$11.33	$6.43	131.0%

The FY 1991 Budget Request for STC's in the BBS Activity is $11.33 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial BBS STC's called for modest increases to bring the centers up to full operational levels. That objective could not be fully met in 1990 due to across-the-board reduction to the Subactivity; the existing centers will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

Science and Technology Centers .... *$ 11,325,000*

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $11.33 million, an increase of $6.43 million, or 131.0 percent, over the FY 1990 Current Plan of $4.9 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$4.15	$5.00	$4.90	$11.33

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

Of the eleven centers funded in February 1989, two are in the BBS Activity, and these investments have already achieved impressive results. For example:

- The Center for Microbial Ecology at Michigan State University is devoted to the basic understanding of microorganisms and their function in natural and human-made habitats. Basic research of microbial ecology has many potential applications such as, improving groundwater quality, hazardous waster disposal, plant pest control, recycling of nutrients, fermentation, and other industrial processes.
- The Center for Development of an Integrated Protein and Nucleic Acid Biotechnology at the California Institute of Technology is focusing on the development of new instrumentation, methodology, and automated techniques necessary for contemporary basic and applied biological research, such as sequencing proteins using very small quantities of

material and sequencing DNA without the use of radioisotopes. These research efforts will impact on all of biology - from the immediate applications to the genome projects, to the new biotechnological products of the future.

CHANGES BETWEEN FY1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Science and Technology Centers	$4.15	$5.00	$4.90	$-0.10	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and the mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Science and Technology Centers	$4.90	$11.33	$6.43	131.0%

The FY 1991 Budget Request for STC's in the BBS Activity is $11.33 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial BBS STC's called for modest increases to bring the centers up to full operational levels. That objective could not be fully met in 1990 due to across-the-board reduction to the Subactivity; the existing centers will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING...$193,250,000

SUMMARY OF REQUEST

The FY 1991 Request for the Computer and Information Science and Engineering Activity is $193.25 million, an increase of $23.46 million, or 13.8 percent, over the FY 1990 Current Plan of $169.79 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Computer and Computation Research	$21.17	$23.67	$21.98	$24.28
Information, Robotics and Intelligent Systems	19.14	21.64	19.98	22.88
Microelectronic Information Processing Systems ...	14.98	18.95	16.61	18.87
Advanced Scientific Computing	55.58	71.69	62.83	62.58
Networking & Communications Research and Infrastructure	17.61	27.13	22.19	31.29
Cross-Disciplinary Activities	17.44	21.42	19.63	24.03
Science & Technology Centers	5.92	6.70	6.57	9.32
Total, Activity	$151.84	$191.20	$169.79	$193.25

NSF ROLE

The Computer and Information Science and Engineering (CISE) Activity:

- Supports research to improve fundamental understanding of computing and information processing;
- Promotes human resource development to contribute to and exploit new knowledge; and
- Supports the operation of advanced national facilities for supercomputing and computer networking.

Computing and communications technologies are both objects of basic research and the key tools of scientific and engineering practice. The ability to advance, use and manage these technologies requires both theoretical and experimental research in many disciplinary fields.

CISE research is multi-disciplinary, involving computer and information scientists, electrical engineers, mathematicians, artificial intelligence and cognitive scientists, and behavioral, economic and social scientists. Support is provided for individual, group, and large scale projects, instrumentation, and infrastructure improvement at academic institutions.

Efforts to increase the human resource base in computing have a high priority. As computing systems have increased in size and complexity, academic computer science and computer engineering have become the essential source of personnel for industry. The CISE Subactivities strengthen and enlarge the human resource base by providing graduate student and postdoctoral support, building strong institutional research capability, increasing Ph.D. production, enlarging the personnel pool by enhancing the flow of minorities into computer and information science and engineering, and training researchers and students in state-of-the-art techniques in computer engineering and advanced scientific computing.

CISE serves the entire U.S. research community by providing access to and development of high performance computing and communications capabilities. National supercomputer research centers make available leading edge computing facilities, train users, and develop advanced software and systems. Networking activities provide a national infrastructure for supercomputer and scientific database access, researcher interaction and information exchange, and research on very advanced capability networks. Both subactivities work cooperatively with industry, and state and regional consortia, and other Federal agencies. Together with research to improve computational tools, CISE programs enable the present scientific era in which complex natural and artificial processes are modeled on computers, and data and research findings are efficiently accessed and disseminated.

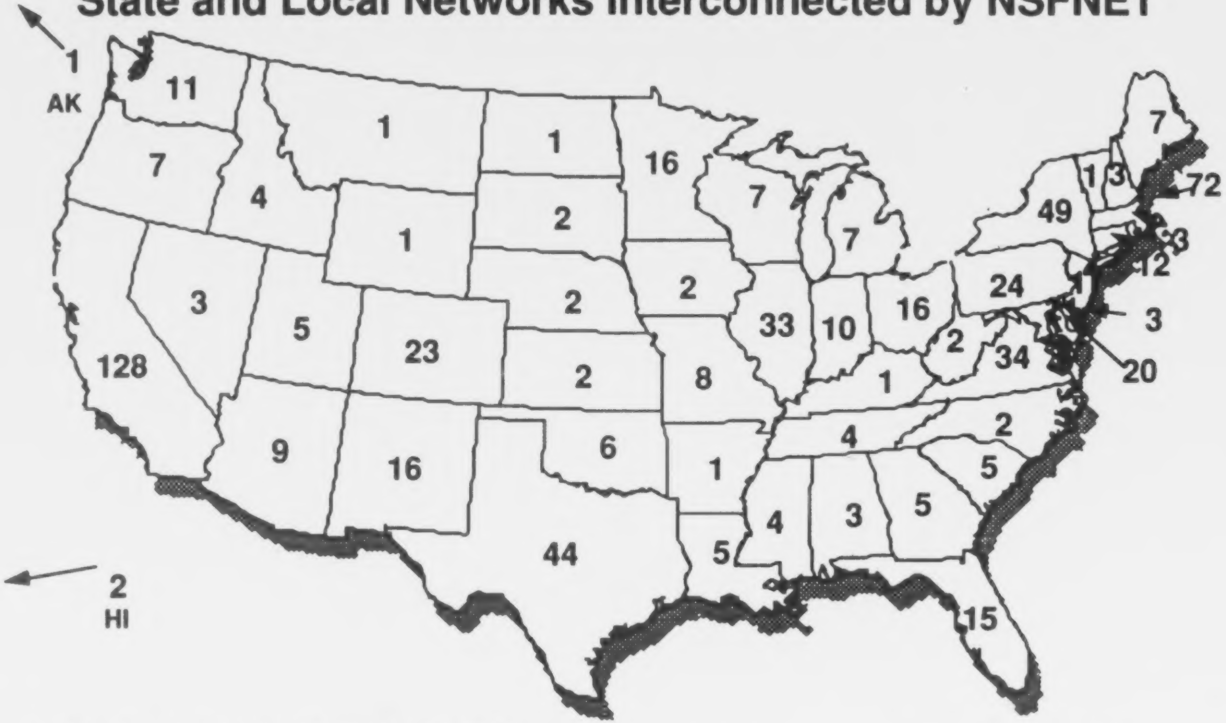
NSF provides more than 40% of all federal obligations for basic research in computer science. Other Federal agencies and industrial firms support research in CISE fields, but focus on specific missions or product lines.

Close coordination is maintained through formal interagency committees, formal agreements, joint participation in National Academy of Science boards, participation in proposal review processes, and by joint support of research. For example, formal joint programs with the Defense Advanced Research Products Agency (DARPA) involve rapid experimental microelectronic circuit fabrication for research and education, software science and engineering, artificial intelligence, and advanced networking research.

NSFNET serves as the core of the national research and education network serving researchers of several agencies (DARPA, NASA, DOE, NSF, HHS, NOAA) which work with NSF to improve and expand research and educational networking. More than 150,000 computers at over 350 academic and industry research institutions in all 50 states have access to the network. Figure 1 shows the distribution of the many state and local networks (each of which may connect many sub-networks) that are interconnected by NSFNET. Major computer and telecommunications companies are partners in the development of NSFNET.

Figure 1

Number of State and Local Networks Interconnected by NSFNET


1
AK
11
7
4
1
1
16
7
7
7
1
3
72
49
3
12
2
1
3
5
23
2
2
33
10
16
24
1
3
20
34
2
128
2
8
1
4
2
9
16
6
1
5
5
44
5
4
3
15
2
HI
PR
2

Total number of networks is 675,
reaching more than 150,000 computers

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Computer and Computation Research . .	$21.17	$23.67	$21.98	$ -1.69	-7.1%
Information, Robotics and Intelligent Systems	19.14	21.64	19.98	-1.66	-7.7
Microelectronic Information Processing Systems	14.98	18.95	16.61	-2.34	-12.4
Advanced Scientific Computing	55.58	71.69	62.83	-8.86	-12.4
Networking & Communications Research and Infrastructure	17.61	27.13	22.19	-4.94	-18.2
Cross-Disciplinary Activities	17.44	21.42	19.63	-1.79	-8.4
Science & Technology Centers	5.92	6.70	6.57	-0.13	-2.0
Total, Activity	$151.84	$191.20	$169.79	$-21.41	-11.1%

The FY 1990 Current Plan is $169.79 million, a decrease of $21.41 million (11.1 percent) from the FY 1990 Request of $191.20 million, due to Congressionally-mandated budget reductions. The Current Plan represents an increase of $17.95 million (11.8 percent) over FY 1989. Disciplinary research project support is increased modestly, with a high priority for improving undergraduate instruction in VLSI design. Human resources improvement at minority institutions is expanded in the Cross-Disciplinary Activities Subactivity. Funding for advanced scientific computing is adjusted for the phase-out of support for the John von Neumann Center and initiation of system upgrades at the other four Centers. NSFNET expansion and development is maintained, with schedules modified to delay major upgrades until FY 1991.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Computer and Computation Research	$21.98	$24.28	$2.30	10.5%
Information, Robotics and Intelligent Systems	19.98	22.88	2.90	14.5
Microelectronic Information Processing Systems	16.61	18.87	2.26	13.6
Advanced Scientific Computing	62.83	62.58	-0.25	-0.4
Networking & Communications Research and Infrastructure	22.19	31.29	9.10	41.0
Cross-Disciplinary Activities	19.63	24.03	4.40	22.4
Science & Technology Centers	6.57	9.32	2.75	41.9
Total, Activity	$169.79	$193.25	$23.46	13.8%

The increase of $23.46 million, or 13.8 percent, in the CISE FY 1991 Request will increase support in two areas: Research and Facilities ($19.06 million) and Education and Human Resources ($4.39 million).

RESEARCH AND FACILITIES

Research activities in the areas of software development ($0.50 million,) high performance software systems ($0.50 million,) and collaboration technology ($0.85 million) will receive special emphasis.

In addition, multi-disciplinary research projects will be initiated in two areas of high leverage for all of scientific and engineering research:

- **Scientific Databases** ($1.75 million): Research efforts in collaboration with users will design, create and test new database technologies and services and initiate the development of enterprises that can be sustained by the user disciplines. There is a major requirement to improve data collection, transmission, and processing. For example, projects will target the geological and biological sciences, supporting global climate change studies, topographical mapping, and mapping nucleotide bases.
- **Application-Specific Computing Systems** ($2.96 million): Research will be initiated on inexpensive, fast, dedicated hardware and software systems tailored to specific computational problems. These will provide computation and cost improvements of two orders of magnitude or more over general purpose computers. Research will focus on new system-level design tools and on system prototyping "kits" that incorporate solutions to such problems as software specification, assembly, and packaging. Scientists and engineers will work with these teams to design and build computing systems tailored to their problems.

In addition to the above research, $2.75 million is requested for new science and technology centers based on proposal pressure in the CISE research areas.

Supercomputing and networking activities are primarily service functions provided to the Foundation's research community as a whole, but they also include important components of computing research to support and extend these technologies and services. The increase strengthens programs initiated in earlier years.

- **Operation and Upgrade of National Supercomputer Centers** ($-0.25 million): Four centers will receive hardware and software upgrades, undertake an integrated program to improve service offerings, and perform new research on computational science software and methods. Although support has been withdrawn from one center, the upgrades at the remaining four effectively double the overall capacity of the NSF supercomputer program.
- **Operation and Upgrade of NSFNET** ($9.00 million): These funds will provide for further development of the NSFNET system to better serve the entire national research and higher education community. This will consist of technical upgrades to improve services and security, transition to international protocol standards, and associated advanced research on very high performance networks and applications.
- **Instrumentation** ($1.00 million): Awards for new experimental equipment on individual investigator research awards will be increased to improve the national infrastructure for basic research in computing.

EDUCATION AND HUMAN RESOURCES

All of the disciplines represented in the CISE Activity are relatively new and rapidly developing, and require special attention to education and human resources. The addition of $0.39 million for the Presidential Young Investigator program and $1.00 million for the Research Initiation program will bolster the large CISE investment for programs presently underway. In addition, $3.00 million are requested for cross-directorate, distributed human resource programs focused on minorities and undergraduate education.

The Research Initiation program will be expanded by about 15 additional awards (bringing the total to about 125), with the goal of increasing participation of new researchers, under-represented groups and "smaller institutions" in CISE research areas. The awards complement and extend to a broader community the PYI program goals of encouraging young faculty to engage in research and education careers.

COMPUTER AND COMPUTATION RESEARCH..........$24,280,000

SUMMARY OF REQUEST

The FY 1991 Request for the Computer and Computation Research (CCR) Subactivity is $24.28 million, an increase of $2.30 million, or 10.5 percent, over the FY 1990 Current Plan of $21.98 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Computer & Computation Theory	$6.42	$6.71	$6.42	$6.89
Numeric & Symbolic Computation	2.83	2.95	3.33	3.99
Computer Systems Architecture	3.10	3.60	3.10	3.21
Software Systems	6.08	6.87	5.87	6.13
Software Engineering	2.74	3.54	3.26	4.06
Total, Subactivity	$21.17	$23.67	$21.98	$24.28

SCIENTIFIC OVERVIEW

Computer and computation research discovers the laws which govern problem-solving procedures and develops computing systems which test and utilize the laws. Topics for study include:

- Strategies and algorithms for solving problems, methods of representing and transforming information;
- Programs and software systems for solving large problems or controlling large systems; and
- Machines for executing programs.

Parallel computation is a basic theme for much of the research supported in the Subactivity. Promising new parallel computer architectures require new algorithms, languages, tools and software systems to be effective. To develop them, new research is required in theory, problem solving, design and implementation.

Research on large software systems is of current national importance. The Subactivity concentrates on fundamental issues in this area, including formal methods in software engineering, the systematic analysis of software artifacts, and distributed tools and programming environments for collaborative software development.

Fundamental research in formal methods and the theory of software engineering often has important practical application. Researchers at Harvard, Carnegie-Mellon and the University of California at Berkeley have invented a method to create software that checks itself against bugs, worms, and viruses. Their techniques will allow software designers to certify that their programs will be secure or correct.

Both academic and industrial computer and computation research are supported by several agencies of the Federal government. However, with the exception of NSF, most Federal programs support mission-directed research. As with industry, most of these Federal programs concentrate their support at a few academic institutions.

NSF provides support in all areas of computer and computation research to a broad range of academic research institutions. This strengthens the Nation's long-term scientific and technology potential by directly involving teaching faculty, graduate and undergraduate student assistants in research, and by providing incentives for university-industry interaction. About 50 percent of academic research in software and 75 percent of research in computing theory is funded by this Subactivity. Close collaboration is maintained with other federal agencies through the Office of Science and Technology Policy, formal interagency agreements and informal interaction of program officers.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Computer & Computation Theory	$6.42	$6.71	$6.42	$-0.29	-4.3%
Numeric & Symbolic Computation	2.83	2.95	3.33	0.38	12.9
Computer Systems Architecture	3.10	3.60	3.10	-0.50	-13.9
Software Systems	6.06	6.87	5.87	-1.00	-14.6
Software Engineering	2.74	3.54	3.26	-0.29	- 8.2
Total, Subactivity	$21.17	$23.67	$21.98	$-1.70	-7.2%

The FY 1990 Current Plan is $21.98 million, a decrease of $1.70 million (7.2 percent) from the FY 1990 Request of $23.67 million, due to Congressionally-mandated reductions. The effects of these reductions are: (1) fewer awards than planned in four programs, (2) decreased emphasis on new computer architectures in order to emphasize software research for high performance computing, and (3) reduction in scope of new efforts in software engineering. The Numeric and Symbolic Computation increase of $0.38 million results from the transfer of research on automatic theorem proving from Software Systems to facilitate coordination between closely related research topics.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Computer & Computation Theory	$6.42	$6.89	$0.47	7.3%
Numeric & Symbolic Computation	3.33	3.99	0.66	19.8
Computer Systems Architecture	3.10	3.21	0.11	3.5
Software Systems	5.87	6.13	0.26	4.4
Software Engineering	3.26	4.06	0.80	24.6
Total, Subactivity	$21.98	$24.28	$2.30	10.5%

The FY 1991 Request increases emphasis on fundamental software research throughout all program elements of the Subactivity. It focuses previous efforts in parallel and distributed systems and scientific computing on the problems of high performance computing by increasing support in the Numeric and Symbolic Computing program element by $0.66 million. It adds support for basic research on methods of software creation by increasing the Software Engineering program element by $0.80 million.

In both public and private sectors, unreliable and inefficient software continues to be a major source of risk to life, property and money. Expansion of fundamental software research will provide methods for increasing software reliability and performance, for testing and validating critical software systems to reduce the risk of failure, and for improving computer, network, and information security and integrity. The potential payoff from this research is exemplified by recent results which indicate that certain kinds of computer programs can be made practically immune to defects. Using a method of constructing software called "k-testability," Richard Lipton of Princeton University has demonstrated that the probability of software failure can be reduced greatly by slowing slightly the speed or performance of the software. Such tradeoffs may be desirable for high risk computer applications.

Finally, new research will be started in software for use of application-specific computing systems, jointly with the Microelectronics Information Processing Systems Subactivity.

INFORMATION, ROBOTICS AND INTELLIGENT SYSTEMS..$22,880,000

SUMMARY OF REQUEST

The FY 1991 Request for the Information, Robotics and Intelligent Systems (IRIS) Subactivity is $22.88 million, an increase of $2.90 million, or 14.5 percent, over the FY 1990 Current Plan of $19.98 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Knowledge and Database Systems	$7.68	$8.21	$7.75	$9.12
Robotics & Machine Intelligence	6.04	6.77	6.24	6.55
Interactive Systems	2.66	3.39	2.66	3.05
Information Technology and Organizations	2.76	3.27	3.33	4.16
Total, Subactivity	$19.14	$21.64	$19.98	$22.88

SCIENTIFIC OVERVIEW

This Subactivity supports research to improve basic understanding and design of information systems that enhance our ability to work and live in complex environments. Research in this Subactivity focuses on how to provide the best computational structures and physical devices to facilitate the use of information. Research to improve understanding of economic and societal consequences of advanced network technologies in organizations and other distributed work environments is also supported.

Databases have become central elements of social and economic functioning, and key factors in scientific research. Similarly, as ways were discovered to automate the transformation of knowledge about processes into physical work, robots and other automated machines have proliferated. Both phenomena have obvious effects on industrial development and growth, and major consequences for national economic competitiveness.

Past technology improvements provide only a hint of the potential usefulness of electronic information processing in the future. Continued progress requires improvements in both theories and techniques for manipulating and using information as well as exploiting the power of new computing machinery. Major opportunities exist to improve the utilization of automated systems and shared knowledge bases, and to exploit computers as intelligent agents in performing complex tasks.

Progress requires fundamental research and engineering experimentation on representing knowledge in machines, and automating complex processes of sensing and understanding, inference, learning, reasoning and problem solving. Equal attention is needed to improving the interaction between people and computers, by understanding the cognitive requirements of human information processing, and by improving the modes of interaction, such as graphic display, multi media input, and high-level mechanisms for human-machine dialogue. Fundamental research is also needed on problems related to advanced scientific communications network applications, such as computer mediated communications, digital journals, collaborative work systems, and retrieval of information from distributed databases.

This Subactivity is a primary source of Federal support for basic interdisciplinary research in computing, neuropsychology, and the behavioral and social sciences dealing with both theory and experimental applications of information processing technology. It provides about 50 percent of the total Federal support for these areas. Other federal agencies, particularly DOD, provide the balance, concentrating on sharply defined and mission-oriented applications.

Industrial laboratories play an important role as consumers of basic university research, but they tend to focus on short term goals leading to marketable products rather than on fundamental knowledge improvement. Significant ambitious national and international efforts in these areas are under way in Japan and in Europe.

Although research in this field is relatively new, significant progress has been made. Of particular importance are advances in the areas of computer vision, and sensor-based robotic systems. For example, a project at Columbia University has created a robot hand which combines tactile and visual sensors, providing and integrating information needed for handling soft materials and accomplishing complex tasks. The experimental system advances the state of the art for automating complex and delicate tasks such as final product assembly and computer assisted surgery.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY1989 Actual	FY1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Knowledge and Database Systems	$7.68	$8.21	$7.75	$-0.48	-5.8%
Robotics & Machine Intelligence	6.04	6.77	6.24	-0.53	-7.8
Interactive Systems	2.66	3.39	2.66	-0.73	-21.5
Information Technology and Organizations	2.76	3.27	3.33	0.06	1.8
Total, Subactivity	$19.14	$21.64	$19.98	$-1.67	-7.7%

The FY 1990 Current Plan is $19.98 million, a decrease of $1.67 million (7.7 percent) from the FY 1990 Request of $21.64 million, due to Congressionally-mandated reductions. This represents a $0.84 million increase over FY 1989. Priorities have been maintained in coordination theory and technology within the Information Technology and Organization Program and machine vision and sensing within the Robotics and Machine Intelligence Program. In line with protecting these priorities, Interactive Systems is level funded.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Chan	
			Amount	Percent
Knowledge and Database Systems	$7.75	$ 9.12	$1.37	17.7%
Robotics & Machine Intelligence	6.24	6.55	0.31	4.9
Interactive Systems	2.66	3.05	0.39	14.6
Information Technology and Organizations	3.33	4.16	0.83	25.0
Total, Subactivity	$19.98	$22.88	$2.90	14.5%

The FY 1991 Request will maintain base support in all program elements to take advantage of computing technologies such as new sensors, parallel computers and high bandwidth communication networks. These technologies, unavailable just a few years ago, are rapidly changing the way information from the physical environment is collected, stored, and used as knowledge for personal and organizational activities.

Most of the increment ($2.60 million) will be allocated to enhance research in two priority areas located primarily in two program elements: Knowledge and Database Systems, and Information Technology and Organizations.

Both of these activities will support work at the intersection of computer science, artificial intelligence, and a variety of scientific and engineering disciplines. Multi-disciplinary teams will be supported to encourage cross-fertilization and to facilitate knowledge transfer between academic and industrial research communities.

- **Scientific Databases** ($1.75 million): This increment in the Knowlege and Database Systems and Interactive Systems programs is to initiate research to advance the database technology essential for improving productivity and enabling new forms of data analysis and knowledge processing in scientific and engineering fields. The goal is to develop new methodologies and enterprises that will be sustained by user disciplines. Application areas in the biological and geological sciences will be targeted so that research results will be useful to initiatives involving global change and the human genome.
- **Collaboration Technology** ($0.85 million): The goal of this research, to be funded primarily within the Information Technology and Organizations program, is to improve methods of using information technologies to improve coordination, communication and resource management of human collaborative activity. Results of this research will contribute to new knowledge and improved tools for humans to function more efficiently in the distributed workplace.

MICROELECTRONICS INFORMATION PROCESSING SYSTEMS..........$18,870,000

SUMMARY OF REQUEST

The FY 1991 Request for the Microelectronics Information Processing Systems (MIPS) Subactivity is $18.87, an increase of $2.26 million, or 13.6 percent, over the FY 1990 Current Plan of $16.61 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Design, Tools & Test	$2.99	$3.30	$3.12	$3.62
Microelectronic Systems Architecture	2.67	3.09	2.84	3.24
Circuits and Signal Processing	3.42	3.78	3.56	3.82
Experimental Systems	4.08	6.07	4.90	5.70
Systems Prototyping & Fabrication	1.82	2.71	2.19	2.49
Total, Subactivity	$14.98	$18.95	$16.61	$18.87

SCIENTIFIC OVERVIEW

The Microelectronics Information Processing Systems (MIPS) Subactivity supports research and education related to the design, prototyping, testing and evaluation of information and signal processing systems. The research includes:

- Analytical, simulation and architectural studies;
- Experimental research on working prototypes of novel computer and information processing systems;
- Improvement of the necessary research tools; and
- An educational component to train the scientists and engineers needed to provide the necessary human resources for this rapidly evolving and changing field.

Improvement in microchip performance is a driving force in the competitiveness of the computer industry. Since 1960, circuit densities have doubled every 18 months. At this rate, 100-million bit chip memories and multi-million transistor single chip processors are within sight, promising new functional capabilities, higher computation rates and lower component prices. At such densities, the central research issues are managing the complexity of design, creating new functional capabilities, and improving the microelectronic fabrication process.

Computational requirements for many advanced scientific and engineering problems can be met by using multi-million dollar supercomputers or alternatively by applying custom microelectronic hardware to the problem at hand. The latter is of particular importance to problems where the dedicated use of a general purpose supercomputer would be too expensive or not possible. Advanced supercomputers and advanced signal processors also use custom devices. The ability to make custom microelectronic devices and systems is key to economic and scientific competitiveness.

Realizing the potential of special purpose computing requires the creation of systems for automating their design and prototyping. A major goal of this Subactivity is to produce the knowledge and mechanisms necessary for the economical and simplified creation of special purpose information processing and computing systems. In order to achieve this goal, fundamental advances are needed in understanding microelectronics systems architecture, and the way systems are designed and prototyped.

The power of application specific computing was demonstrated in a project at the University of North Carolina, which is jointly supported by DARPA. The prototype system developed in the project is capable of generating complex graphics over 100 times faster than conventional high performance graphics workstations. Subsequent versions promise equivalent improvements in the speed at which scientific graphics can be produced.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Design, Tools & Test	$ 2.99	$ 3.30	$ 3.12	$-0.18	-5.5%
Microelectronic Systems Architecture	2.67	3.09	2.84	-0.25	-8.1
Circuits and Signal Processing	3.42	3.78	3.56	-0.22	-5.8
Experimental Systems	4.08	6.07	4.90	-1.17	-19.2
Systems Prototyping & Fabrication	1.82	2.71	2.19	-0.52	-19.2
Total, Subactivity	$14.98	$18.95	$16.61	$-2.34	-12.3%

The FY 1990 Current Plan is $16.61 million, a decrease of $2.34 million (12.3 percent) from the FY 1990 Request of $18.95 million, due to Congressionally-mandated reductions. The FY 1990 Current Plan is an increase of $1.63 million (10.9 percent) over the FY 1989 level; all program elements are funded above FY 1989 levels. The Experimental Systems and Systems Prototyping and Fabrication Program Elements are given priority because of the need for building and doing experimental research on new promising systems.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Design, Tools & Test	$ 3.12	$ 3.62	$0.50	15.9%
Microelectronic Systems Architecture	2.84	3.24	0.40	14.1
Circuits and Signal Processing	3.56	3.82	0.26	7.2
Experimental Systems	4.90	5.70	0.80	16.3
Systems Prototyping & Fabrication	2.19	2.49	0.30	13.7
Total, Subactivity	$16.61	$18.87	$2.26	13.6%

Most of the requested increase is for the Application-Specific Computing Systems (ASCS) initiative ($1.96 million), which involves all of the program elements in the Subactivity. The focus is on the problems associated with designing, building, testing and evaluating these systems. Many of the techniques and tools necessary for designing them will also be useful for designing general purpose computers.

The objectives are to:

- Support research on the design and evaluation of special purpose computing architectures, emphasizing the high level design phases which involve performance prediction of alternative designs;
- Improve design techniques and knowledge associated with ASCS design, especially as imbedded in computer aided design tools and in libraries of hardware and software components;
- Build and evaluate experimental systems to validate newly developed design techniques and ensure that systems design focuses on realizable systems that meet performance goals;
- Make simple system building easy and complex system building possible by improving services for fabricating chips, boards, and systems and for building prototypes rapidly;
- Support interdisciplinary research that brings together application expertise and computing system designers; and
- Train students to design and build digital hardware/software systems.

Research supported under this new thrust will produce experimental hardware and accompanying software to test the applicability of applications specific systems technology to real problems of high performance computing in scientific and engineering research applications.

ADVANCED SCIENTIFIC COMPUTING...$62,580,000

SUMMARY OF REQUEST

The FY 1991 Request for the Advanced Scientific Computing (ASC) subactivity is $62.58 million, a decrease of $0.25 million, or 0.4 percent, from the FY 1990 Current Plan of $62.83 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Centers	$53.79	$69.03	$60.21	$59.59
New Technologies	1.79	2.66	2.62	2.99
Total, Subactivity	$55.58	$71.69	$62.83	$62.58

SCIENTIFIC OVERVIEW

The Advanced Scientific Computing Subactivity provides the science and engineering basic research community access to advanced computational facilities through support of four nationally accessible Supercomputer Research Centers:

- The San Diego Supercomputer Center at the University of California at San Diego;
- The National Center for Supercomputing Applications at the University of Illinois;
- The Pittsburgh Supercomputing Center; and
- The Cornell National Supercomputer Facility at Cornell University.

The Subactivity also supports basic research on methods and technologies for high performance scientific computing.

The Centers serve the U.S. academic research community, support software development to maximize productivity, and train new users. In addition, the Centers, working jointly with industry, are leaders in research on supercomputing systems including state-of-the-art supercomputers and software, peripherals for data storage, retrieval and display, network connections, and special purpose processors.

State-of-the-art high performance computers are essential to leadership in contemporary scientific and engineering research, as they permit researchers to explore otherwise unmanageable problems. Operating at speeds of from ten to one hundred times faster than mainframe computers, or up to billions of operations per second, supercomputers are used to analyze data and simulate processes at levels of complexity and detail that inform our most advanced notions of reality.

The range and diversity of research addressed is vast: from modelling the surfaces of viruses to simulating the dynamics of thunderstorms; from performing calculations to reveal new features of nucleon masses; to building models of international economic activity. As a result, the centers serve scientists and engineers from all the Foundation activities. Each year, more than 5,000 university faculty, postdoctoral, graduate and undergraduate students, and industrial researchers from across the nation use the Centers. These researchers come from all types of institutions and from every field.

The NSF Supercomputing program provides researcher William Krakauer of the College of William and Mary ready access to the advanced high performance computing technology required for his research on tungsten. In physical processes such as catalysis and corrosion, the surface of a material are where all the action takes place. Using the Cornell National Supercomputer Facility and proceeding from equations representing atomic interactions, Dr. Krakauer has simulated the behavior of a small number (30) of tungsten atoms in an attempt to predict surface properties at a variety of temperatures. Faster supercomputers in the future will allow the simulation of larger numbers of atoms for more realistic sample sizes.

To meet the growing demand for access and speed, the computing systems at the Centers were upgraded in 1989. Major equipment was added for data storage and scientific visualization, and new supercomputers were acquired. These upgrades resulted in a doubling of raw processing capacity, and a very substantial improvement on the capability available to the U. S. research community.

In addition to providing access to supercomputers, the Centers provide a broad array of critical user services: specialized graphics and visualization systems, applications software libraries and consulting services, training workshops, and related activities. Educational activities range from special programs for high-school students and undergraduates, through established disciplinary research programs at the post doctoral level.

The Centers also receive support from industrial affiliates, and work with them on new ways to use high performance computing for increased productivity. For example, ALCOA Laboratories' partnership with the Pittsburgh Supercomputing Center has resulted in the ability to test a new can design more quickly and at a cost of about $2,000 per test, rather than $100,000 per test required for traditional physical prototyping.

NSF activities in this area are coordinated with the more mission-oriented activities of other Federal agencies, most notably the Department of Energy, Department of Defense, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration. This cooperation encourages the exchange of skills, applications, software, operations and management experience, and optimizes facility utilization.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Centers	$53.79	$69.03	$60.21	$ -8.82	-12.8%
New Technologies	1.79	2.66	2.62	-0.04	- 1.7
Total, Subactivity	$55.58	$71.69	$62.83	$ -8.86	-12.4%

The Subactivity is funded at $62.83 million in FY 1990, $8.86 million (12.4 perecent) below the Request level. The reduction is taken in the Supercomputer Centers program element and reflects the lower costs due to the phasing out of support for the John von Neumann Center. This nets out to a $6.42 million real increase over FY 1989, for systems upgrades at the four remaining centers. The New Technologies research program element is maintained near the FY 1990 Request level, which is an increase of $0.83 million, or 46.4 percent, over FY 1989, in order to bolster software research for high performance computing applications.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Centers	$60.21	$59.59	$-0.62	-1.0%
New Technologies	2.62	2.99	0.37	14.3
Total, Subactivity	$62.83	$62.58	$-0.25	-0.4%

The Request supports existing upgrade programs at the four national centers at the cooperative agreement levels, and enhances research activities in technologies supporting high performance computing. Although the decrease for the Centers program element is $0.62 million, this represents a net increase of $7.38 million over the FY 1990 Current Plan for the four remaining centers, which will support renewal and upgrades. Computing services and resources and educational activities will be extended to a broader national constituency. A wider spectrum of computational science and engineering research activities will be addressed through the New Technologies program element, with special attention to topics where the research domains of computer science and disciplinary computing intersect.

The Subactivity will support incorporation of new highly-parallel supercomputers into operations at the national centers. Research related to mapping promising applications onto these new systems, and increasing support for parallel computing on conventional production supercomputer systems will be accelerated.

Overall system performance and research productivity can be significantly increased by using more efficient software and algorithms. Along with expansion of application libraries, upgrading dataset management systems, and improvement of visualization and graphics capabilities, the Subactivity will expand its support of research on new computational algorithms and software development.

Research will be supported to develop automated tools for improvement of user software and to provide users with a more robust, friendly computing environment. The interface to systems is central in this regard. Software is required to enable researchers to move seamlessly from personal workstations, through local computing systems, to the national centers, accessing applications software and tools in each environment. Implementation of a standard operating environment in all centers systems is central to this goal.

In order to enhance the scientific environment of the centers, additional support will be offered for research associate programs, visitors programs, research workshop series, summer research institutes and extended programs for select disciplinary topics.

Cooperative efforts between the national centers in such areas as development of on-line tools and documentation, management of large databases, scientific visualization and software development will be initiated. Emphasis will be placed on development of generic tools for use at the national centers with distribution to state and local supercomputer centers.

The centers have developed extensive education and training programs, resources, and expertise and have put into place mechanisms for propagating these efforts. Education and training programs will span the entire user base, with special emphasis on introducing the methods and experience of scientific computing to undergraduate students. The centers will continue to integrate use of the supercomputer systems into undergraduate curricula of many disciplines at both local and non-local institutions. Opportunities for training scientists and students at institutions lacking formal affiliation with the centers will be made available, along with special programs for researchers at minority institutions.

NETWORKING AND COMMUNICATIONS RESEARCH AND INFRASTRUCTURE...$31,290,000

SUMMARY OF REQUEST

The FY 1991 Request for the Networking and Communications Research and Infrastructure (NCRI) Subactivity is $31.29 million, an increase of $9.10 million, or 41.0 percent, over the FY 1990 Current Plan of $22.19 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
NSFNET	$13.59	$19.63	$15.96	$22.04
Networking & Communications Research	4.02	7.50	6.23	9.25
Total, Subactivity	$17.61	$27.13	$22.19	$31.29

SCIENTIFIC OVERVIEW

The Networking and Communications Research and Infrastructure Subactivity supports the development and operation of the NSFNET computer network for research and education, and fundamental scientific and engineering research on communications theory and data networks. The research and network service functions are integrated, creating the mechanism for fast translation of research into practice and driving research toward new problems based on experience.

This provides a vehicle for testing research results and a natural opportunity for university/industry collaboration. In addition to stimulating academic research in a highly leveraged way, this approach affords the use of new technology developed and deployed by the telecommunications industry, such as high bandwidth fiber optic communications lines, at low marginal cost.

NSFNET, a network of computer networks, or internet, was created in 1986 to provide access to the NSF Supercomputer Centers for the nation's computational science community. It has grown into a transcontinental backbone network interconnecting more than a dozen autonomous regional networks, which in turn connect nearly 300 academic, industrial and governmental research institutions. Through this network, researchers can link to each other for research collaboration, and to unique resources such as advanced supercomputers, radio telescope arrays and biotechnology databases.

Collaborative development of national and international networking with other Federal agencies results in effective interaction across the Nation. The NSFNET backbone is the centerpiece of the internet composed of connected Federal agency networks, regional mid-level networks, and local wide area networks. Together, they form the prototype of a national research and education network.

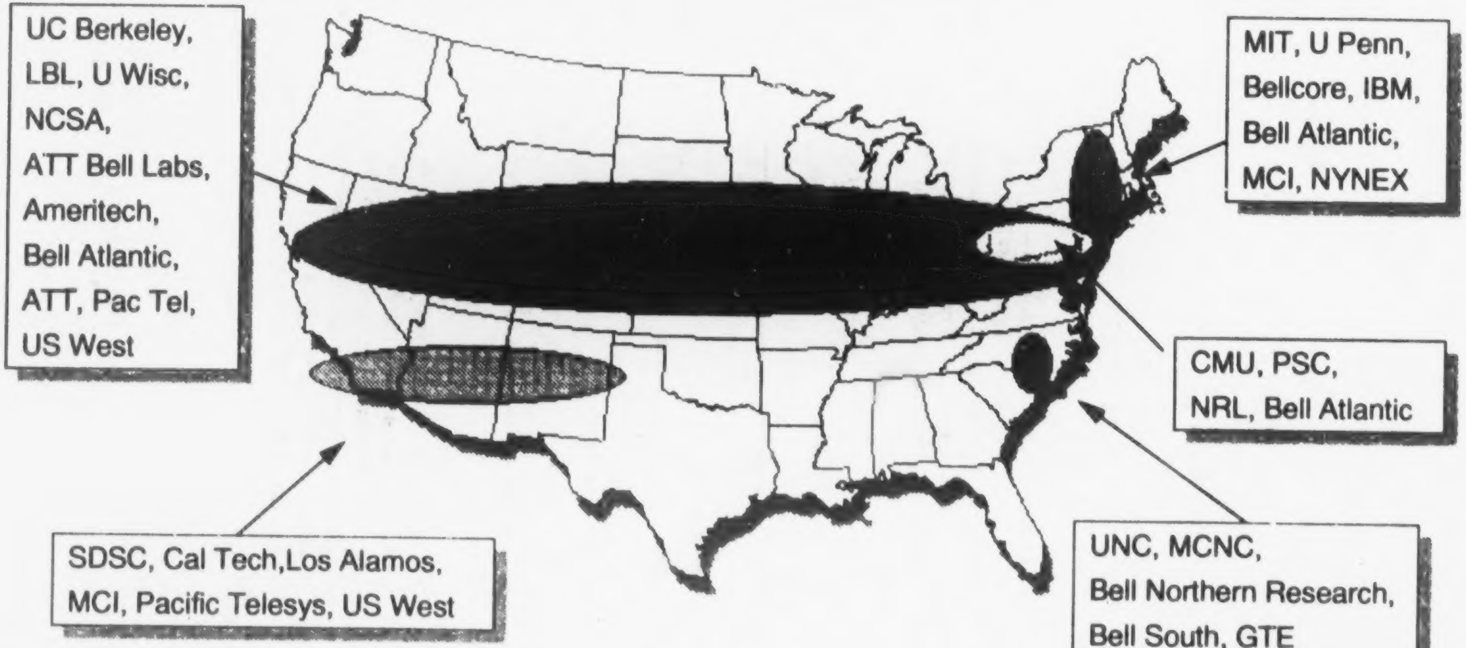
NSF is leading the Federal interagency implementation of the national research and education network. Cooperating closely with five other agencies to interconnect their cross-country research networks, the NSFNET backbone has been upgraded and reconfigured to accommodate substantial growth in usage.

Although operational and pilot networks are the most visible parts of the Subactivity, progress depends on an aggressive program of research in communications sciences and engineering. Projects are supported at the forefront of technology and application. For example, research performed by principal investigators Ezio Biglieri and Kung Yao at the University of California, Los Angeles, has resulted in new architectures to implement advanced signal processing algorithms used in high-speed data communication systems. The new machines are fault tolerant, and a major advance for insuring reliable, secure computer networks.

Research often benefits from substantial industrial participation and is positioned to transfer directly into practice, thereby enhancing the Nation's industrial strength. This is demonstrated in a joint initiative of NSF, DARPA and U.S. industry, which began in 1989. It involves the creation and operation of national "testbed" networks for advanced research on problems associated with super-high speed data transmission. Each testbed uses an advanced scientific research application to stress and improve the underlying technology. A significant feature of the project is very substantial industrial participation and cost sharing. Industry partners include the nation's major communications common carriers and computer vendors and their research laboratories. They are working with several National Laboratories, NSF Supercomputer Centers, and university researchers in a truly national program. The testbeds and participants are illustrated in Figure 2.

Figure 2

Advanced High Speed Network Research
Industry-University-Government Research Testbeds


UC Berkeley,
LBL, U Wisc,
NCSA,
ATT Bell Labs,
Ameritech,
Bell Atlantic,
ATT, Pac Tel,
US West
MIT, U Penn,
Bellcore, IBM,
Bell Atlantic,
MCI, NYNEX
CMU, PSC,
NRL, Bell Atlantic
SDSC, Cal Tech,Los Alamos,
MCI, Pacific Telesys, US West
UNC, MCNC,
Bell Northern Research,
Bell South, GTE

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
NSFNET	$13.59	$19.63	$15.96	$-3.67	-18.7%
Networking & Communication ; Research	4.02	7.50	6.23	-1.27	-16.9
Total, Subactivity	$17.61	$27.13	$22.19	$-4.94	-18.2%

The FY 1990 Current Plan is $22.19 million, a decrease of $4.94 million (18.2 percent) from the request level of $27.13 million, due to Congressionally-mandated reductions. The decrease is spread over all programs with priority given to assistance to regional networks of the NSFNET and to primarily undergraduate institutions. The FY 1990 Current Plan also represents an increase of $4.58 million over the FY 1989 level, which will sustain the planned NSFNET activity.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
NSFNET	$15.96	$22.04	$6.08	38.1%
Networking & Communications Research	6.23	9.25	3.02	48.5
Total, Subactivity	$22.19	$31.29	$9.10	41.0%

The FY 1991 Request continues the capacity expansion of the NSFNET backbone network, primarily for increasing the transmission speed from 1.5 million bits per second (T1) to 45 million bits per second (T3). Additional funding will be provided to regional networks to assist their capacity expansion in cases where scientific need is demonstrated. User services will be expanded and more closely coordinated with those offered by other agencies supporting research networks. This will initiate service integration, and create a single point of contact and assistance for Internet users.

The requested increase for the Networking and Communications research program element will be used for three purposes:

- The number of awards for disciplinary fundamental research will be increased;
- Funding is increased for the network technology component of program in coordination theory and collaboration technology funded jointly with two other Subactivities in CISE; and
- The coordinated interagency program of research and technology demonstration in networks operating at speeds in excess of a billion bits per second will continue into its third year.

CROSS-DISCIPLINARY ACTIVITIES..$24,030,000

SUMMARY OF REQUEST

The FY 1991 Request for the Cross-Disciplinary Activities (CDA) Subactivity is $24.03 million, an increase of $4.40 million, or 22.4 percent, over the FY 1990 Current Plan of $19.63 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
CISE Institutional Infrastructure	$14.95	$18.93	$17.14	$20.54
CISE Instrumentation	2.49	2.49	2.49	3.49
Total, Subactivity	$17.44	$21.42	$19.63	$24.03

SCIENTIFIC OVERVIEW

The Cross-Disciplinary Activities Subactivity manages and coordinates programs that cut across the CISE Activity. All are focused on improving the human and material infrastructure for computing research and education in the Nation's universities and colleges. The Subactivity also coordinates NSF-wide education and human resource activities within CISE.

Improving institutional capability for both research and education is a major priority. Advances in the young field of computing are rapid, human resources are in short supply for both universities and industry, and laboratories and facilities are in need of rapid renewal and updating to stay abreast of the present state of the art.

Special efforts are made to initiate support for both research and educational infrastructure development in minority institutions, and to enable major improvements in the curriculum and teaching environment. This is done by supporting equipment acquisition, maintenance, technical support staff, and other appropriate expenditures. For improving undergraduate education, support is provided for curriculum development, faculty enhancement, and instructional laboratory equipment.

The infrastructure building activities of CDA have achieved a significant record of success in stimulating experimental research in computer and information science and engineering areas, and in increasing the number of Ph.D. graduates in computer research fields. This has resulted in a significant improvement in the human resources available for industry, academia, and government.

Infrastructure building programs were extended to minority institutions in FY 1989. The focus on minority institutions recognizes the changing composition of the U.S. labor force, and the need for more people with advanced skills in all areas of computer and information science and engineering. In the first year of this program, institutions receiving support have developed specific plans for increasing the output of bachelor level graduates and in sending more into graduate study.

Based on the recommendations of a 1988 Workshop on Computer Science Education, an "educational infrastructure" activity was created to stimulate needed innovative educational activities and development of effective courses and curricula for undergraduate training in computer and information science and engineering. Each project will be led by an outstanding senior scientist and will have the potential for nationwide impact.

The CISE Instrumentation program element provides awards for the acquisition of shared equipment and software not generally available on individual project awards. Equipment provided by the Subactivity enables experimental research in all areas of CISE research program support.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY1990 Current Plan	Change	
				Amount	Percent
CISE Institutional Infrastructure	$14.95	$18.93	$17.14	$-1.79	-9.5%
CISE Instrumentation	2.49	2.49	2.49	0.00	-0.0
Total, Subactivity	$17.44	$21.42	$19.63	$-1.79	-8.4%

The FY 1990 Current Plan is $19.63 million, a decrease of $1.79 (8.4 percent) million from the FY 1990 Request of $21.42 million, due to Congressionally-mandated reductions. It represents an increase of $2.19 million (12.6 percent) over FY 1989. This allows the Subactivity to expand infrastructure building in minority institutions and to begin projects to improve the undergraduate curriculum in computer science.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
CISE Institutional Infrastructure	$17.14	$20.54	$3.40	19.8%
CISE Instrumentation	2.49	3.49	1.00	40.1
Total, Subactivity	$19.63	$24.03	$4.40	22.4%

The FY 1991 Request will increase educational and human resource activities within the Institutional Infrastructure and Instrumentation program elements.

- The infrastructure building activity will be expanded and there will be a significant increase in the component focussed on undergraduate education and minority activities.
- The increase in the Instrumentation element will support essential workstation and related equipment acquisitions for researchers throughout the CISE community.

The increase for projects focused in minority institutions within the Institutional Infrastructure program element responds to the need for more people with advanced training in all areas of computer and information science and engineering. By both upgrading facilities and providing for enhancement of the academic programs in predominantly minority institutions, a part of the goal of increasing the opportunities for minorities in these fields can be achieved. The increase will support larger awards and expand the program to additional minority institutions.

Support will be focused, as well, on smaller institutions and small departments to improve their infrastructure for research and teaching. This will increase the number of awards made to such institutions and thereby increase the capacity for outstanding research and education in computer and information science and engineering. Additional projects will be started to improve the curriculum.

An incentive matching program using funds from both the disciplinary programs in CISE and the Instrumentation element will be established to provide support for acquiring essential workstations.

Science and Technology Centers $9,320,000

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $9.32 million, an increase of $2.75 million, or 41.9 percent, over the FY 1990 Current Plan of $6.57 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$5.92	$6.70	$6.57	$9.32

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

Two of the eleven centers funded in February 1989 are in the CISE Activity, and these investments have already achieved impressive results. For example:

- Rutgers and Princeton Universities have joined together for an STC in Discrete Mathematics and Theoretical Computer Science. They are complemented by a major effort of AT&T Bell Labs and Bellcore, which brings the applications of these activities to bear on a variety of practical areas.
- The STC for Research on Parallel Computation at Rice University is working on making parallel-processing computers easier to use, especially for scientific applications. The center, attempting to convey the excitement of computational science, held a week-long workshop for secondary school math and science teachers. The issue of attracting and retaining minority scientists was the focus, and Rice faculty, the President of Rice, major industrial employers, such as Exxon and Shell, and the former director of the U.S. Immigration and Naturalization Service spoke at this well-attended workshop.

CHANGES BETWEEN FY1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Science and Technology Centers	$5.92	$6.70	$6.57	$-0.13	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Science and Technology Centers	$6.57	$9.32	$2.75	41.9%

The FY 1991 Budget Request for STC's in the CISE Activity is $9.32 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial CISE STC's called for modest increases to bring the centers up to full operational levels. That objective could not be fully met in 1990 due to the across-the-board reduction to the Subactivity; the existing centers will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

ENGINEERING *$226,000,000*

Summary of Request

The FY 1991 Budget Request for the Engineering Activity is $226.00 million, an increase of $25.78 million, or 12.9 percent, over the FY 1990 Current Plan of $200.22 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Biological and Critical Systems	$34.07	$36.36	$35.60	$36.13
Chemical and Thermal Systems	30.98	32.71	30.67	33.14
Electrical and Communications Systems	29.87	32.84	29.71	31.81
Mechanical and Structural Systems	23.04	24.39	22.70	24.41
Design and Manufacturing Systems	18.05	19.90	18.29	19.77
Engineering Centers	40.43	49.00	46.43	55.31
Engineering Infrastructure Development	10.62	16.00	16.82	25.43
Total, Activity	$187.06	$211.20	$200.22	$226.00

NSF ROLE

NSF's Engineering (ENG) Activity seeks to promote the progress of engineering and technology in the U.S. in order to: 1) ensure that the Nation stays in the forefront of engineering research and education; 2) improve national prosperity and quality of life; 3) contribute to national security; and 4) respond to future technological opportunities and needs.

ENG accomplishes its mission by supporting research and education at all levels and in all fields of engineering; developing the Nation's engineering resources; and stimulating changes in the culture of the engineering profession to meet the Nation's needs. ENG serves as a catalyst for new ideas and innovations and as a leader in establishing future directions for the engineering community.

As we enter the 21st century, the economic strength and security of the U.S. will depend upon maintaining superior technology. Engineers and engineering research play a key role in maintaining and strengthening the Nation's technology base by providing the link between scientific advances and the introduction of new processes and products.

For example, ENG supports research to develop and expand the engineering foundations of design and manufacturing across a broad spectrum of American industry, such as chemical and materials processing, energy, machine tools, telecommunications, and pharmaceuticals. This long term effort is needed to deepen our understanding of the processes, operations and systems which comprise our manufacturing base; to render this base more competitive; and to make it responsive to new needs and receptive to innovation.

Before the end of the century, the emerging field of nanoengineering promises to revolutionize manufacturing, communications and medicine, as well as provide many new consumer products. Building on the technologies developed for the ultra-miniaturization of electronics, NSF-supported researchers have already been able to fabricate micro-size sensors, actuators, motors, phones, lamps, filters, surgical tools, and robots, along with techniques for controlling chemical micro-reactions, micro-channel cooling and fluid microdispersions.

The ENG Activity specific goals are to:

- Strengthen the engineering knowledge base, which provides the foundation for engineering education, research, technological innovation and practice.
- Encourage technological innovation through the support of research in critical and emerging areas, and encourage the transfer of research results to the private sector.
- Promote the cross-disciplinary and systems-oriented research approach through the support of multi-investigator research groups and centers.
- Improve the quality of engineering education in order to attract the best students to the engineering profession and produce world class engineers capable of design, integration, synthesis and complex problem solving.
- Encourage greater numbers of minorities, women, and the disabled to participate in engineering education and research through programs designed to remove barriers and provide new incentives and opportunities.

The timely achievement of the latter objective is especially critical in order to prevent the major shortfall of engineers at all levels that is projected by the end of the next decade.

To accomplish its objectives, ENG seeks a balance in the programs it supports: between individual investigator research projects, group projects and research center programs; between mature fields and emerging fields; between knowledge-driven fields and experience-driven fields; and between cross-disciplinary and disciplinary research.

NSF's engineering programs address the overall health of engineering research and education, as contrasted with the focused agendas of mission agencies. NSF provides about 27 percent of the total Federal support for engineering research in academia. Other significant agencies include the Department of Defense, the Department of Energy and the National Aeronautics and Space Administration. The following table shows Federal support for research in FY 1988 by fields of engineering.

FEDERAL SUPPORT FOR THE CONDUCT OF RESEARCH TO UNIVERSITIES AND COLLEGES
FISCAL YEAR 1988

AGENCY	NSF	DOD	DOE	NASA	OTHER AGENCIES
AERONAUTICAL/ASTRONAUTICAL	*	54%	*	45%	*
CHEMICAL ENGINEERING	60%	4	32%	3	*
CIVIL ENGINEERING	70	26	4	*	*
ELECTRICAL ENGINEERING	37	57	*	5	*
MECHANICAL ENGINEERING	39	37	14	10	*
METALLURGICAL/MATERIALS	13	67	12	7	*
OTHER FIELDS	14	16	9	15	46%
TOTAL ENGINEERING	27%	44%	9%	12%	8%

* LESS THAN ONE PERCENT

SOURCE: NSF, SCIENCE RESOURCE STUDIES DIVISION

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Biological and Critical Systems	$34.07	$36.36	$35.60	-$0.76	-2.1%
Chemical and Thermal Systems	30.98	32.71	30.67	-2.04	-6.2
Electrical and Communications Systems .	29.87	32.84	29.71	-3.13	-9.5
Mechanical and Structural Systems	23.04	24.38	22.70	-1.68	-6.9
Design and Manufacturing Systems	18.05	19.90	18.29	-1.61	-8.1
Engineering Centers	40.43	49.00	46.43	-2.57	-5.2
Engineering Infrastructure Development ..	10.62	16.00	16.82	0.82	5.1
Total, Activity	$187.06	$211.20	$200.22	-$10.98	-5.2%

The FY 1990 Current Plan is $200.22 million, which is a decrease of $10.98 million, or 5.2 percent, from the FY 1990 Budget Request of $211.20 million. This represents the Activity's share of the Congressionally-mandated reductions. This is, however, $13.16 Million above FY 1989, or an increase of 7.0 percent. While the Engineering Centers Subactivity is reduced by $2.57 million, or 5.2 percent from its requested level, sufficient funds are provided to start three new Engineering Research Centers and several Industry/University Cooperative Research Centers. The Engineering Infrastructure Development Subactivity is increased by 5.1 percent over its request in order to expand support for undergraduate engineering education and for women, minority and disabled graduate students.

The Biological and Critical Systems Subactivity includes $2.00 million for earthquake hazard mitigation research transferred from funds appropriated in response to the Loma Prieta earthquake.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Biological and Critical Systems	$35.60	$36.13	$0.53	1.5%
Chemical and Thermal Systems	30.67	33.14	2.47	8.1
Electrical and Communications Systems	29.71	31.81	2.10	7.1
Mechanical and Structural Systems	22.70	24.41	1.71	7.5
Design and Manufacturing Systems	18.29	19.77	1.48	8.1
Engineering Centers	46.43	55.31	8.88	19.1
Engineering Infrastructure Development	16.82	25.43	8.61	51.2
Total, Activity	$200.22	$226.00	$25.78	12.9%

The ENG Activity is increased by $25.78 million or 12.9 percent over the FY 1990 Current Plan, to a total of $226.00 million. The FY 1991 Request incorporates the Foundation's central budget themes:

RESEARCH AND FACILITIES

The support of research and facilities continues to be an important mission in ENG. The FY 1991 request provides the following:

- An increase of $5.70 million, or 5.9 percent, to $102 million to augment research support, including instrumentation and equipment, in a number of important topics such as downstream biochemical processing; optical high-speed communications; design and manufacturing; hazard mitigation; and engineering research to prevent or alleviate damage to the environment.
- A special emphasis on research on the processing of advanced materials, such as polymers, ceramics, composites, superconductors, biomaterials, microstructures, and membranes. The processing of these materials frequently involves synthesis and control at the molecular level; advanced surface modification technologies; novel processing methods; and integration with device and applications manufacturing.
- A $7.50 million increase for Engineering Research Centers, from $42.57 to $50.07 million. A recent study by the National Academy of Engineering has concluded that the current $2.40 million average annual funding for centers is not adequate to achieve the original ERC program objectives. This increase will be distributed over the existing set of nineteen centers, considering both need and performance. No new centers will be started.

- An increase of $1.38 million for the Industry/University Cooperative Research Centers to fund four new university research centers aimed at broadening the program's interaction with state governments. Developed in conjunction with the National Governor's Association, this approach will enhance the coordination of state government, industry, academia and NSF in developing science and engineering approaches to regional economic development.
- A $1.75 million increase for continued support for ongoing initiatives in strategic manufacturing; neuroengineering; optical communications; biotechnology; and environmental and ocean engineering systems.

EDUCATION AND HUMAN RESOURCES

ENG programs are aimed at expanding the human resource pool and improving the quality of engineers and engineering education at all levels. For the Nation to have sufficient engineering human resources for the 21st century, significantly more women and minorities must be attracted to graduate engineering programs.

The FY 1991 Request provides an increase of $12.00 million, to $51.10 million, for engineering education and human resources. This request includes:

- An increase of $5.00 million, to $11.00 million, to start two new engineering education coalitions, bringing the total number funded by NSF to five. The SEE Activity is also contributing $4.00 million to this effort. These coalitions are aimed at dramatically increasing the quality of undergraduate engineering education by designing, implementing, evaluating and disseminating new teaching structures, approaches and technologies.
- $1.00 million to support focused pilot projects aimed at developing model undergraduate engineering courses and laboratories at the introductory level, and promoting the introduction of new teaching technologies. ENG will work with SEE to evaluate research results and models.
- $3.80 million to expand cross-directorate undergraduate programs, such as Research Experiences for Undergraduates (REU) and Research in Undergraduate Institutions (RUI). Also support is provided for a new cross-directorate Alliances for Minority Participation program, which will encourage undergraduate minority students to pursue graduate studies in science and engineering.
- A $0.70 million increase, to $4.40 million, for special programs to expand the participation of women, minorities and the disabled in engineering education and research. This includes funds to double the numbers of graduate fellowships, from 40 to 80, for women and minority students, in addition to a similar increase in the SEE Activity for Women in Engineering.
- Expansion of the Presidential Young Investigators (PYI) program to support an additional 22 young faculty members. Total FY 1991 ENG program funding is $21.20 million, which supports approximately 375 PYIs. In FY 1988 industrial cost-sharing totaled about $8.70 million.
- Support for a new cross-directorate program, Faculty Awards for Women, which will recognize and support outstanding women scientists and engineers.

CHANGES IN BUDGET STRUCTURE

In FY 1990 the ENG Activity established the new Subactivity, Engineering Infrastructure Development (EID) to provide a clearer management focus for ENG support of engineering education, equipment and instrumentation, and programs to develop human resources. The Subactivity has four Program Elements: Engineering Education; Human Resources Development; Physical Infrastructure Development; and Special Studies and Analyses.

EID supports and provides coordination within ENG for activities designed to strengthen the Nation's engineering infrastructure, and develop the quality of engineering professionals essential to continuously improving the competitive position of the United States. EID also coordinates the participation of ENG in many of the Foundation's cross-directorate programs, such as Research Experiences for Undergraduates (REU) and Research Opportunities for Women (ROW).

Prior to this restructuring, EID's programs and activities were funded by contributions from the other ENG Subactivities and managed by ENG's Office of Engineering Infrastructure Development. The results of the restructuring are shown in the crosswalk table below. The new structure increases the number of ENG Subactivities from six to seven and the number of program elements from 22 to 26. No research topic that was supported under the old structure has been eliminated.

In addition, the FY 1990 amounts transferred to EID from the other Subactivities, as shown in the subtotals for EID, show the heavy emphasis that ENG has placed on education and human resources activities. As a result of both this restructuring and increased emphasis on education and human resources, many of the Subactivities and program elements will show relatively flat funding, or minor decreases, from FY 1989 to FY 1990.

FY 1990 CURRENT PLAN
ENGINEERING ACTIVITY CROSSWALK

(DOLLARS IN MILLIONS)

NSF ENGINEERING PROGRAM SUBACTIVITIES AND PROGRAM ELEMENTS	PROPOSED ENGINEERING SUBACTIVITIES						
	Chemical, & Thermal Systems	Mechanical & Structural Systems	Electrical, & Communic. Systems	Design, & Manufac. Systems	Biological & Critical Systems	Engineering Centers Division	TOTAL
BIOLOGICAL & CRITICAL SYSTEMS DIVISION (BCS)							
Bioengineering & Aiding the Disabled					11.33		11.33
Environmental & Ocean Systems					5.43		5.43
Earthquake Hazard Mitigation					14.32		14.32
Transfer pursuant to PL 101-130					2.00		2.00
Natural and Man-Made Hazard Mitigation					2.52		2.52
Subtotal, BCS	0.00	0.00	0.00	0.00	35.60	0.00	35.60
CHEMICAL AND THERMAL SYSTEMS DIVISION (CTS)							
Chemical Reaction Processes	6.60						6.60
Interfacial, Transp & Separations Process	7.90						7.90
Thermal Systems	7.55						7.55
Fluid, Particulate & Hydraulic Systems	8.62						8.62
Subtotal, CTS	30.67	0.00	0.00	0.00	0.00	0.00	30.67
ELECTRICAL AND COMMUNICATIONS SYSTEMS DIVISION (ECS)							
Quantum Electronics, Waves and Beams			7.95				7.95
Solid State and Microstructures			8.05				8.05
Computational & Communications Systems			4.05				4.05
Engineering Systems			6.23				6.23
Emerging Technologies Initiation			1.03				1.03
Subtotal, ECS	0.00	0.00	29.71	0.00	0.00	0.00	29.71
MECHANICAL AND STRUCTURAL SYSTEMS DIVISION (MSS)							
Dynamic Systems and Control		3.13					3.13
Structures and Building Systems		6.62					6.62
Materials Engineering and Tribology		7.00					7.00
Solid and Geomechanics		5.95					5.95
Subtotal, MSS	0.00	22.70	0.00	0.00	0.00	0.00	22.70
DESIGN AND MANUFACTURING SYSTEMS DIVISION (DMS)							
Operations Research & Production Systems				5.00			5.00
Design & Computer-Integrated Engineering				5.94			5.94
Manufacturing Processes & Equipment				7.35			7.35
Subtotal, DMS	0.00	0.00	0.00	18.29	0.00	0.00	18.29
ENGINEERING CENTERS DIVISION (ECD)							
Engineering Research Centers						42.57	42.57
Industry/University Cooperative Research Centers						3.86	3.86
Subtotal, ECD	0.00	0.00	0.00	0.00	0.00	46.43	46.43
ENGINEERING INFRASTRUCTURE DEVELOPMENT DIVISION (EID)							
Engineering Education	1.26	0.89	1.25	0.76	1.39	0.45	6.00
Human Resources Development	1.36	0.96	1.35	0.82	1.52	0.51	6.52
Physical Infrastructure Development	0.52	0.36	0.51	0.31	0.58	0.19	2.47
Special Studies and Analyses	0.38	0.27	0.38	0.23	0.43	0.14	1.83
Subtotal, EID	3.52	2.48	3.49	2.12	3.92	1.29	16.82
Total, ENG	34.19	25.18	33.20	20.41	39.52	47.72	200.22

BIOLOGICAL AND CRITICAL SYSTEMS......................................$36,130,000

SUMMARY OF REQUEST

The FY 1991 Request for the Biological and Critical Systems (BCS) Subactivity is $36.13 million, an increase of $0.53 million, or 1.5 percent, over the FY 1990 Current Plan of $35.60 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Bioengineering and Aiding the Disabled	$11.38	$12.57	$11.33	$12.28
Environmental & Ocean Systems	5.29	5.58	5.43	5.90
Earthquake Hazard Mitigation	14.84	15.48	14.32	15.25
Transfer pursuant to P.L. 101-130	0.00	0.00	2.00	0.00
Natural and Man-Made Hazard Mitigation	2.56	2.73	2.52	2.70
Total, Subactivity	$34.07	$36.36	$35.60	$36.13

SCIENTIFIC OVERVIEW

The BCS Subactivity is comprised of two areas of activity: (1) Bioengineering and Environmental Systems; and (2) Hazard Mitigation.

The Bioengineering and Environmental Systems area is concerned with expanding the knowledge base of bioengineering, in improving the ability to cope with threats to the physical environment, and in exploring basic engineering problems in the development, conservation and use of ocean resources and systems.

The cross-disciplinary field of bioengineering applies engineering principles to:

- The development of new and improved technology for human health care and aids for the disabled;
- The understanding of living systems; and
- The scale-up and production of new products derived from advances in biology.

BCS-supported research has resulted in new processes to recover important high molecular weight proteins for human health care.

The Undergraduate Design Projects initiative is an example of efforts to strengthen human resources in engineering. The initiative provides funds to undergraduate students to provide custom designed devices and software for specific disabled individuals. This initiative has been very successful in developing helpful aids to the disabled and in providing a new dimension to the education of some 80 engineering undergraduates.

Research in environmental engineering involves the use of electron beam technology to fracture chlorinated groundwater contaminants and force combination with "designer" particles, and the use of microorganisms for the beneficial treatment of soils. Ocean engineering research involves autonomous underwater vehicles and synthesis and design methodology for large structures, for example.

The Hazard Mitigation area seeks to develop a basic engineering understanding of potentially destructive natural phenomena such as earthquakes, floods, sea level rise, green house effects, expanding and collapsing soils, destructive winds, landslides, and storm surges.

NSF supported evaluations of physical and economical damage caused by Hurricane Hugo and the Loma Prieta earthquake. These evaluations will be followed by research studies to reduce the consequences of future similar events. Effective natural hazard mitigation requires the availability and dissemination of information. NSF plays a leading role through the establishment and support of the National Information Service for Earthquake Engineering, the Natural Hazard Information Center, and the National Center for Earthquake Engineering Research.

Major cooperative research programs have been initiated in wind engineering at Texas Tech University and Colorado State University, and in earthquake engineering involving the use of large centrifuge facilities at several institutions including the University of California at Davis and the University of Colorado. Combining human and laboratory resources at these cooperative institutions will produce significant progress in the engineering field.

NSF Natural Hazards research involves many cooperative activities with other Federal and state agencies, and also many international programs with countries such as Japan, Taiwan, The Peoples Republic of China, and the Soviet Union.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Bioengineering and Aiding the Disabled	$11.38	$12.57	$11.33	-$1.24	-9.9%
Environmental & Ocean Systems	5.29	5.58	5.43	-0.15	-2.7
Earthquake Hazard Mitigation	14.84	15.48	14.32	-1.16	-7.5
Transfer pursuant to P.L. 101-130	0.00	0.00	2.00	2.00	N/A
Natural and Man-Made Hazard Mitigation	2.56	2.73	2.52	-0.21	-7.7
Total, Subactivity	$34.07	$36.36	$35.60	-$0.76	-2.1%

The FY 1990 Current Plan is $35.60 million, which is a net decrease of $0.76 million, or 2.1 percent, from the FY 1990 Budget Request of $36.36 million. The Subactivity benefited from $2.00 million appropriated in response to the Loma Prieta earthquake. Without these additional funds, the decrease is $2.76 million, or 7.6 percent, below the request, which represents the Subactivity's share of the Congressionally-mandated budget reductions. All program elements were reduced, except Environmental and Ocean Systems, which was only reduced by 2.7 percent in order to protect the relatively small base support for ocean systems research.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Bioengineering and Aiding the Disabled	$11.33	$12.28	$0.95	8.4%
Environmental & Ocean Systems	5.43	5.90	0.47	8.7
Earthquake Hazard Mitigation	14.32	15.25	0.93	6.5
Transfer pursuant to P.L. 101-130	2.00	0.00	-2.00	N/A
~~Natural and Man-Made Hazard~~ Mitigation	2.52	2.70	0.18	7.1
Total, Subactivity	$35.60	$36.13	$0.53	1.5%

The FY 1991 Request for the Biological and Critical Systems Subactivity is $36.13 million, a net increase of $0.53 million, or 1.5 percent over the FY 1990 Current Plan of $35.60 million, due to $2.00 million transferred in FY 1990 for earthquake hazards mitigation research in responre to the Loma Prieta earthquake. The real increase over FY 1990 provided for the Subactivity programs is $2.53 million, or 7.5 percent. This increase provides for:

- Augmentation of the downstream processing of bioproducts thrust within the Bioengineering and Aiding the Disabled program. This would include novel bioreactor designs and new methods for separation and purification of bioproducts on a commercial scale.
- Also within the same program, new research on tissue replacement materials, "smart" biomaterials involving molecular self-assemble, adhesive proteins, and bioelectronics materials.
- Initiation of research on waste management practices that adversely impact coastal environmental quality.
- Initiation of earthquake hazards mitigation research on seismic resistant active control systems for structures in earthquake prone areas. Some of this activity will be carried out cooperatively with Japanese researchers who have done research in this area.
- Continuation of research that is conducted as part of the International Decade for Natural Disaster Reduction, in coordination with other Federal agencies such as the U.S. Geological Survey and National Oceanic and Atmospheric Administration.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $3.92 million was transferred in FY 1990 from the BCS Subactivity to the new EID Subactivity. This amount reflects BCS' share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

CHEMICAL AND THERMAL SYSTEMS..$33,140,000

SUMMARY OF REQUEST

The FY 1991 Request for the Chemical and Thermal Systems (CTS) Subactivity is $33.14 million, an increase of $2.47 million, or 8.1 percent, over the FY 1990 Current Plan of $30.67 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Chemical Reaction Processes	$6.74	$6.72	$6.60	$7.00
Interfacial, Transport and Separations Processes ...	7.62	8.97	7.90	8.77
Thermal Systems	7.81	7.99	7.55	8.15
Fluid, Particulate and Hydraulic Systems	8.81	9.03	8.62	9.22
Total, Subactivity	$30.98	$32.71	$30.67	$33.14

SCIENTIFIC OVERVIEW

The CTS Subactivity funds research which strengthens the fundamental engineering base for technologies involving chemical, thermal and flow processes. The processes are important in areas like microelectronics, commodity and specialty chemicals, pharmaceuticals, energy production and transfer, molecular engineering of advanced materials, and chemical processing of hazardous waste.

CTS frequently coordinates special initiatives with other NSF and Federal programs. For example, research projects are jointly supported with NSF's Chemistry and Materials Research Subactivities involving the chemical processing of materials for the improvement of the manufacturing of microelectronics chips and thin film sensing devices.

In one project supported jointly with Materials Research, researchers at the California Institute of Technology are seeking to produce and characterize uniform-sized gallium arsenide clusters in the 5 to 20 nanometer size range. Such small clusters are called quantum dots because their small dimensions yield discrete electronic states. Exciting new electronic and optical components would result from the incorporation of large numbers of identical quantum cluster dots into solid state structures. Possible applications include semiconductor lasers of an intensity several orders of magnitude higher than conventional diode lasers and new electroluminescent display technology with convenient adjustment of color.

CTS provides a substantial fraction of the Federal research support to the university chemical engineering community. This support helps to provide a fertile research environment for technological innovation and to train future generations of engineers who can deal effectively with technologies involving chemical and thermal processes.

The efforts of CTS are carried out in close cooperation with related Federal agencies. For example, self-assembling microstructures are jointly studied with the Naval Research Laboratory.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Chemical Reaction Processes	$6.74	$6.72	$6.60	-$0.12	-1.8%
Interfacial, Transport and Separations Processes	7.62	8.97	7.90	-1.07	-11.9
Thermal Systems	7.81	7.99	7.55	-0.44	-5.5
Fluid, Particulate and Hydraulic Systems	8.81	9.03	8.62	-0.41	-4.5
Total, Subactivity	$30.98	$32.71	$30.67	-$2.04	-6.2%

The FY 1990 Current Plan is $30.67 million, which is a decrease of $2.04 million, or 6.2 percent, from the FY 1990 Budget Request of $32.71 million. This represents the Subactivity's share of the Congressionally-mandated budget reductions. The Interfacial, Transport and Separations Processes program, due to the importance of its research thrust in microscale chemical processing, received an increase of $0.28 million over FY 1989.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Chemical Reaction Processes	$6.60	$7.00	$0.40	6.1%
Interfacial, Transport and Separations Processes	7.90	8.77	0.87	11.0
Thermal Systems	7.55	8.15	0.60	7.9
Fluid, Particulate and Hydraulic Systems	8.62	9.22	0.60	7.0
Total, Subactivity	$30.67	$33.14	$2.47	8.1%

CTS research programs are increased by $2.47 million, from $30.67 to $33.14 million, or 8.1 percent. This provides for increased research on the following topics:

- Within the Thermal Systems program, research on combustion and chemical processes related to processing of materials of high purity. These include the magnetic stabilization of crystal melts, combustion synthesis of powdered ceramics, and environmentally compatible combustion processes.
- Within the Chemical Reaction Processes program, research on new chemical reaction processes, including: photocatalysis and electrosynthesis, sol-gel processing, processing of catalysts with molecularly engineered pore volumes and activities, and chemical processing of advanced materials.
- Within the Fluid, Particulate and Hydraulic Systems program, research on the characterization and modeling flow of fluids with microscopic structure, such as polymeric solutions and particulate mixtures, with applications to thin films, coatings, ceramic slurries, and sediment flow.
- Within the Interfacial, Transport and Separations Processes program, research on the development of microporous synthetic materials for bio-separations membranes with high selectivity; processing of advanced electronic and optical materials; and separations processes of environmental importance. Also included is increased support for the thrust in microscale chemical processing, which is a joint effort with the Mathematical and Physical Sciences Activity.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $3.52 million was transferred in FY 1990 from the CTS Subactivity to the new EID Subactivity. This amount reflects CTS' share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

ELECTRICAL AND COMMUNICATIONS SYSTEMS....................$31,810,000

SUMMARY OF REQUEST

The FY 1990 Request for the Electrical and Communications Systems (ECS) Subactivity is $31.81 million, an increase of $2.10 million, or 7.1 percent, over the FY 1990 Current Plan of $29.71 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Quantum Electronics, Waves and Beams	$7.95	$8.93	$7.95	$8.50
Solid State and Microstructures	9.03	9.47	8.85	9.40
Communications and Computational Systems	4.86	5.51	4.85	5.45
Engineering Systems	6.21	6.20	6.23	6.63
Emerging Technologies Initiation	1.82	2.73	1.83	1.83
Total, Subactivity	$29.87	$32.84	$29.71	$31.81

SCIENTIFIC OVERVIEW

The ECS Subactivity directs its efforts towards enhancing the engineering knowledge base for electrical, electronic, electromechanical or optical technologies. It also develops the tools and techniques for computational simulation in engineering research, and generic principles and methodologies that support engineering systems.

ECS supports semiconductor and related device research that is central to advances in microelectronic and optoelectronic technologies. Research emphasizes new device concepts in structures at nanoscale dimensions, x-ray lithography and novel processing technologies, including laser and plasma assisted methods. For example, research supported at MIT has led to novel methods of microgap x-ray nanolithography for fabrication of nanostructures.

Increased emphasis is being placed on optical communication and computation research in the ECS Subactivity, based on the growing national importance of this research area. ECS has traditionally supported cutting-edge research in optoelectronic materials and devices. The Communications and Computational program is initiating support for systems level integration to complement this research.

In order to assure efficient use of available financial resources, ECS coordinates funding of its researchers with other Federal funds. One of its more effective activities in this area has been the use by NSF grantees of the state-of-the-art Army microelectronics facility at Fort Monmouth, New Jersey.

As part of an ongoing effort to keep abreast of foreign science and technology, ECS manages the Japanese Technology Evaluation Center (JTEC) in collaboration with the Department of Commerce, the Departments of Energy and Defense, NASA, and other Federal agencies. Recent JTEC assessments have evaluated Japanese R&D in such nationally important areas as high-temperature superconductivity and high-definition television.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Quantum Electronics, Waves and Beams	$7.95	$8.93	$7.95	-$0.98	-11.0%
Solid State and Microstructures	9.03	9.47	8.85	-0.62	-6.5
Communications and Computational Systems	4.86	5.51	4.85	-0.66	-12.0
Engineering Systems	6.21	6.20	6.23	0.03	0.5
Emerging Technologies Initiation	1.82	2.73	1.83	-0.90	-33.0
Total, Subactivity	$29.87	$32.84	$29.71	-$3.13	-9.5%

The FY 1990 Current Plan is $29.71 million, which is a decrease of $3.13 million, or 9.5 percent, from the FY 1990 Budget Request of $32.84 million. This represents the Subactivity's share of the Congressionally-mandated budget reductions, applied to all program elements except Engineering Systems. That program increased slightly over FY 1989 to augment research on control mechanisms for large complex systems for manufacturing and electric power transmission. The Emerging Technologies Program was reduced by 33.0 percent from its request. This reflects a decision not to fund any new projects in FY 1990 pending an evaluation of that program.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Quantum Electronics, Waves and Beams	$7.95	$8.50	$0.55	6.9%
Solid State and Microstructures	8.85	9.40	0.55	6.2
Communications and Computational Systems	4.85	5.45	0.60	12.4
Engineering Systems	6.23	6.63	0.40	6.4
Emerging Technologies Initiation	1.83	1.83	0.00	0.0
Total, Subactivity	$29.71	$31.81	$2.10	7.1%

ECS is requesting a total of $31.81 million, an increase of $2.10 million, or 7.1 percent over the FY 1990 Current Plan of $29.71 million. The incremental funds will be used to augment research in the following areas:

- Within the Solid State and Microstructures program, low-temperature plasmas for plasma-assisted materials processing and related microelectronic processing technologies.
- Within the Quantum Electronics, Waves and Beams program, the development of advanced optoelectronic devices and materials for high-speed optical communications.
- Within the Communications and Computational Systems program, critical problems at the interface of optical materials, devices and systems research, which must be solved before the potential of all-optical networks can be achieved.
- Within the Engineering Systems program, the development of design techniques for the analysis and synthesis of complex feedback control systems with emphasis on electric power systems, including improvements in stability, reliability, and power quality.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $3.49 million was transferred in FY 1990 from the ECS Subactivity to the new EID Subactivity. This amount reflects ECS' share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

Also in FY 1990, $2.00 million was transferred from the Communications and Computational Systems (CCS) element to the Solid State and Microstructures (SSM) element. The purpose was to provide continuing support for research in solid state sensors and microelectromechanical devices. Such research is more appropriately part of the SSM program, which focuses on experimental work in solid state devices and microstructures rather than the CCS program, which focuses on computational methods and algorithms.

MECHANICAL AND STRUCTURAL SYSTEMS..............................$24,410,000

SUMMARY OF REQUEST

The FY 1991 Request for the Mechanical and Structural Systems (MSS) Subactivity is $24.41 million, an increase of $1.71 million, or 7.5 percent, over the FY 1990 Current Plan of $22.70 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Dynamic Systems and Control	$3.18	$3.36	$3.13	$3.35
Structures and Building Systems	6.66	7.18	6.62	7.10
Materials Engineering and Tribology	7.12	7.40	7.00	7.54
Solid and Geomechanics	6.08	6.45	5.95	6.42
Total, Subactivity	$23.04	$24.39	$22.70	$24.41

SCIENTIFIC OVERVIEW

The MSS Subactivity seeks to expand fundamental engineering knowledge in mechanics, structures, materials engineering, and mechanical systems. Research supports:

- The design and control of machine systems with superior performance characteristics;
- The creation of new and more cost effective structures;
- The understanding of mechanisms for deterioration of constructed structures; and
- Fundamental research in geomechanics to improve ground stability and performance of surface and subsurface structures.

Materials processing is a relatively new field in academic research, and involves several disciplines such as solid mechanics, tribology, and materials and structural engineering. Research is directed at developing advanced processing methods for newly engineered and difficult-to-process materials, such as materials used in the production of superconductors.

For example, researchers at North Carolina State University have developed a novel process for depositing thin films of superconducting material directly onto silicon and other substrates. The group used this process to obtain previously unsurpassed current-carrying capacities. The use of high-temperature superconductors may lead to a new generation of ultra-fast computers.

The efforts of MSS are carried out with a careful consideration and assessment of related support by other Federal agencies and U.S. industry, as well as related areas in foreign countries. Many projects are jointly supported between this Subactivity and other agencies.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Dynamic Systems and Control	$3.18	$3.36	$3.13	-$0.23	-6.8%
Structures and Building Systems	6.66	7.18	6.62	-0.56	-7.8
Materials Engineering and Tribology	7.12	7.40	7.00	-0.40	-5.4
Solid and Geomechanics.	6.08	6.45	5.95	-0.50	-7.8
Total, Subactivity	$23.04	$24.39	$22.70	-$1.69	-6.9%

The FY 1990 Current Plan is $22.70 million, which is a decrease of $1.69 million, or 6.9 percent, from the FY 1990 Budget Request of $24.39 million. This represents the Subactivity's share of the Congressionally-mandated budget reductions, and adjustments were made to all program elements.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Dynamic Systems and Control	$3.13	$3.35	$0.22	7.0%
Structures and Building Systems	6.62	7.10	0.48	7.3
Materials Engineering and Tribology	7.00	7.54	0.54	7.7
Solid and Geomechanics	5.95	6.42	0.47	7.9
Total, Subactivity	$22.70	$24.41	$1.71	7.5%

The FY 1991 request is $24.41 million, an increase of $1.71 million, or 7.5 percent, over the FY 1990 Current Plan of $22.70 million. These additional funds will be used to increase the number of individual investigator and group grants in the following areas:

- Materials Engineering research to develop novel processing methods, such as superplastic forming, which involve both modeling and sophisticated microstructural control.
- Within the Dynamic Systems and Control program, design of intelligent control systems to perform a variety of tasks, adapt to changing requirements, and maintain and repair themselves for maximum up-time.
- Within the Structures and Building Systems program, quantitative nondestructive evaluation of materials and large structural systems. Breakthroughs in this area could improve the safety of structures.
- Within the Solid and Geomechanics program, establishment of a test site for geotechnical engineering research. This field site would be a national resource for use by industrial and academic researchers.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $2.48 million was transferred in FY 1990 from the MSS Subactivity to the new EID Subactivity. This amount reflects MSS' share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

DESIGN AND MANUFACTURING SYSTEMS.................................$19,770,000

SUMMARY OF REQUEST

The FY 1991 Request for the Design and Manufacturing Systems (DDM) Subactivity is $19.77 million, an increase of $1.48 million, or 8.1 percent, over the FY 1990 Current Plan of $18.29 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Operations Research and Production Systems	$4.69	$5.25	$5.00	$5.71
Design and Computer-Integrated Engineering	6.02	6.55	5.94	6.33
Manufacturing Processes and Equipment	7.35	8.10	7.35	7.73
Total, Subactivity	$18.06	$19.90	$18.29	$19.77

SCIENTIFIC OVERVIEW

The DDM Subactivity seeks to expand the scientific foundations of design, manufacturing and computer-integrated engineering. This long-term effort will deepen our understanding of the processes, operations and systems which comprise our manufacturing base and make the base more receptive to innovation. The long range goal is enhanced manufacturing efficiency and integration of all production and logistics operations into flexible and adaptable systems. Complementing the effort is support of the development of operations research methodologies that underlie the full range of engineering production systems.

The key issues in these areas involve computer integration of design and manufacturing processes by means of new, more versatile software, and the exploration of novel materials modification and transformation techniques. Such issues underlie the Nation's attempt to enhance its productivity gains. For example, DDM-supported researchers at the University of Texas, Austin recently produced three-dimensional parts by sintering successive layers of powder with a laser. The computer automated process facilitates the rapid production of prototype parts, which will greatly reduce product development time.

Research on manufacturing equipment, such as machine tools, is directed at increasing performance levels, which are measured in terms of higher material removal rate, greater precision, and longer operating life.

With the goal of moving manufacturing technology frontiers ahead through major innovations, DDM developed the Strategic Manufacturing Initiative. In FY 1989, seven interdisciplinary group grants totaling $1.70 million were awarded. In FY 1990 the Department of Defense will also participate in this initiative.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Operations Research & Production Systems	$4.69	$5.25	$5.00	-$0.25	-4.8%
Design and Computer-Integrated Engineering	6.02	6.55	5.94	-0.61	-9.3
Manufacturing Processes and Equipment . .	7.35	8.10	7.35	-0.75	-9.3
Total, Subactivity	$18.06	$19.90	$18.29	-$1.61	-8.1%

The FY 1990 Current Plan is $18.29 million, which is a decrease of $1.61 million, or 8.1 percent, from the FY 1990 Budget Request of $19.90 million. This represents the Subactivity's share of the Congressionally-mandated budget reductions, and adjustments were made to all program elements. However, Operations Research and Production Systems received a smaller percentage reduction in order to fund a new research thrust in engineering and technology management for the computer-integrated enterprise.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Operations Research and Production Systems	$5.00	$5.71	$0.71	14.2%
Design and Computer-Integrated Engineering	5.94	6.33	0.39	6.6
Manufacturing Processes and Equipment	7.35	7.73	0.38	5.2
Total, Subactivity	$18.29	$19.77	$1.48	8.1%

The DDM Subactivity increases by $1.48 million, or 8.1 percent, over the FY 1990 Current Plan of $18.29 million for additional research on strategic manufacturing topics, such as:

- Within the Operations Research and Production Systems program, 1) integrating manufacturing processes and systems, such as simultaneous consideration of function, design, materials, and manufacturing processes; 2) integrating information on parts design, planning, scheduling, materials handling and processing.
- Within the Manufacturing Processes and Equipment program, 1) developing advanced processing methods for newly engineered and difficult-to-process materials, and 2) next generation machine tools and manufacturing equipment to achieve superior performance and reliability.
- Within the Design and Computer-Integrated Engineering program, Rapid Prototyping: i.e., modular and distributed test-bed systems using advanced data bases and user interfaces to perform rapid design, manufacture, assembly and simulation of new products.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $2.12 million was transferred in FY 1990 from the DDM Subactivity to the new EID Subactivity. This amount reflects DDM's share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

ENGINEERING CENTERS $55,310,000

SUMMARY OF REQUEST

The FY 1991 Request for the Engineering Centers (ECD) Subactivity is $55.31 million, an increase of $8.88 million, or 19.1 percent, over the FY 1990 Current Plan of $46.43 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Engineering Research Centers	$37.18	$44.32	$42.57	$50.07
Industry/University Cooperative Research Centers ..	3.25	4.68	3.86	5.24
Total, Subactivity	$40.43	$49.00	$46.43	$55.31

SCIENTIFIC OVERVIEW

The ECD Subactivity supports university-based research centers aimed at enhancing U.S. industrial competitiveness by strengthening university/industry coupling in research and education. The Centers focus research teams on knowledge breakthroughs underlying technological advances and increase cooperation among university engineers, scientists and their industrial counterparts. A major goal is to improve engineering education to better prepare students for engineering practice.

Engineering Research Centers (ERC) Program

The ERCs emphasize the development of long-term strategic research leading to technological advances and an improved understanding of the integration and management of engineering systems. Emphasis is placed on involving graduate and undergraduate students in designing, integrating and managing technological systems. Each Center develops its research and education programs in close collaboration with industry to enhance technology transfer.

Currently there are 19 centers established in universities across the country. They are listed below under the major technological areas upon which they focus:

MANUFACTURING AND DESIGN

- Carnegie-Mellon University-- Engineering Design
- University of Maryland/Harvard University -- Systems Research

- Ohio State University -- Net Shape Manufacturing
- Purdue University -- Intelligent Manufacturing Systems
- Mississippi State University -- Geometrically-Complex Field Problems

MATERIALS PROCESSING FOR MANUFACTURING

- University of Minnesota -- Interfacial Engineering
- University of Wisconsin/University of Minnesota -- Plasma-Aided Manufacturing

OPTOELECTRONICS, MICROELECTRONICS, TELECOMMUNICATIONS

- University of Colorado/Colorado State University -- Optical Computing Systems
- Columbia University -- Telecommunications Research
- University of Illinois/Urbana -- Compound Semiconductor Microelectronics
- North Carolina State University/other North Carolina universities -- Advanced Electronic Materials Processing
- Carnegie-Mellon University -- Data Storage Systems

BIOTECHNOLOGY/BIOENGINEERING

- Duke University/other North Carolina universities -- Emerging Cardiovascular Technologies
- Massachusetts Institute of Technology -- Biotechnology Process Engineering
- Montana State University -- Interfacial Microbial Process Engineering

RESOURCE RECOVERY/UTILIZATION & INFRASTRUCTURE

- Brigham Young University/University of Utah -- Advanced Combustion Technology
- University of California/Los Angeles -- Hazardous Substance Control
- Texas A&M University/University of Texas -- Offshore Technology
- Lehigh University -- Advanced Technology for Large Structural Systems

Some examples of activities underway in the various centers are:

- The Lehigh University ERC for Advanced Technology for Large Structural Systems (ATLSS) has perfected the ATLSS Connection. Designed and developed through the collaboration of faculty from several disciplines with the Center's industry partners, it has the potential for great impact on fabrication, erection and reliability of large structures.
- The Systems Research Center at the University of Maryland has established a broad program for industrial collaboration and technology transfer. It includes joint research projects, visitor programs, shared use of laboratories, and fellowship programs with in-

dustry. The Center has joined with the University of Maryland's small business incubator program to support the initiation of a small business focused on a fiber-optic switching system.

- The ERC for Net Shape Manufacturing at Ohio State University has established a strong manufacturing educational program and has been innovative in creating a special industrially sponsored fellowship program to encourage students of U.S. nationality to study manufacturing.
- The ERC on Advanced Electronic Materials Processing at North Carolina State University has provided summer internships in the Center to eight students from four predominantly minority universities. These internships were so rewarding and exciting for the students, that all eight have decided to pursue graduate studies.

The ERC Program is a partnership among NSF, State Governments, some 400 firms and academia. These sectors have joined in support of the ERC concept to more than double NSF's annual contribution to the Centers. These are augmented by substantial one-time contributions of new buildings and laboratories.

Industry/University Cooperative Research Centers (I/UCRC) Program

This program encourages industry/university cooperation by developing research programs defined by the industries supporting each Center. On average, the Centers attract ten times the support provided by NSF through contributions from firms and several states. NSF support is initiated through a planning grant and operational centers receive continued NSF support for 5 years, after which they must become self-supporting with a combination of industrial, State, and other Federal support.

By the end of FY 1990, there will be 48 operational centers. The I/UCRCs carry out research in a variety of areas including polymer and glass processing; plastics recycling; nondestructive evaluation; chemical process control; sensors and actuators; computer graphics and software engineering; and surface science.

For example, the I/UCRC for Plastics Recycling Research at Rutgers University has licensed technology to an engineering firm to build and operate a plastics recycling plant at Bridgeport, New Jersey. The plant, started in October 1989 with a potential capacity of 50 million pounds per year, will employ 50 people. Three other similar plants are scheduled to begin operations soon.

A unique aspect of the I/UCRC Program is the development of "TIE" joint research projects between two or more centers. Institutional resources and facilities are pooled to focus on a research agenda that neither Center could attempt alone. For example, a "TIE" project studying "Plant Wide Control" involving the capabilities of the University of Tennessee's I/UCRC for Measurement and Controls Engineering and Lehigh University's I/UCRC on Chemical Process Modeling, has developed data that resulted in one member company saving $200,000 per year on plant operations.

The Industry/University Cooperative Research Fellowships provide new opportunities for faculty, staff or advanced students to spend up to 6 months conducting research at one of the I/UCRC's industrial member's facilities, learning more about industrially relevant research.

The I/UCRC program co-funds, with the NSF/SEE's Young Scholars program, projects which involve middle school students in exciting research projects at selected I/UCRCs. The program will also begin a new initiative, co-funded by the SEE-Teacher Enhancement program, to provide summer support to middle school teachers which will enable them to participate in research activities at three I/UCRCs.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Engineering Research Centers	$37.18	$44.32	$42.57	-$1.75	-3.9%
Industry/University Cooperative Research Centers	3.25	4.68	3.86	-0.82	-17.5
Total, Subactivity	$40.43	$49.00	$46.43	-$2.57	-5.2%

The FY 1990 Current Plan is $46.43 million, which is a decrease of $2.57 million, or 5.2 percent, from the FY 1990 Budget Request of $49.00 million. This represents the Subactivity's share of Congressionally-mandated budget reductions. The Engineering Research Centers program increased by $5.40 million over FY 1989, enough to fund three new centers. The I/UCRC program was substantially reduced from its FY 1990 request but received an increase of $0.61 million, or 18.8 percent, which was used to start several new centers and provide "seed" funding for an initiative with state governments.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Engineering Research Centers	$42.57	$50.07	$7.50	17.6%
Industry/University Cooperative Research Centers	3.86	5.24	1.38	35.8
Total, Subactivity	$46.43	$55.31	$8.88	19.1%

The $8.88 million increase in the FY 1991 Request, to a total of $55.31 million, represents a 19.1 percent increase over the FY 1990 Current Plan of $46.43 million. This includes:

- A $7.50 million increase for Engineering Research Centers. A recent study by the National Academy of Engineering concluded that the current $2.40 million average annual funding for centers is not adequate to achieve the original ERC program objectives. This increase will be distributed over the existing set of nineteen centers, considering both need and performance; no new centers are planned for FY 1991. The increase also provides funds for centers to expand research activities for undergraduate students, particularly women and minorities.
- An increase of $1.38 million, from $3.86 to $5.24 million, for the Industry/University Cooperative Research Centers. $1.00 million of this increase will be used to fund four new university research centers aimed at broadening the program's interaction with state governments. Operational centers will be supported by the States, NSF, and industry in equal shares. Developed in conjunction with the National Governor's Association, this approach will enhance the coordination of the states, industry, academia and NSF in developing science and engineering approaches to regional economic development.
- The remaining $0.38 million will be used to establish several new I/UCRCs in emerging research areas.

CHANGES IN BUDGET STRUCTURE

As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, $1.29 million was transferred in FY 1990 from the ECD Subactivity to the new EID Subactivity. This amount reflects ECD's share of the funding responsibility for broad engineering education and infrastructure development activities that are now located in the EID Subactivity.

ENGINEERING INFRASTRUCTURE DEVELOPMENT..............$25,430,000

SUMMARY OF REQUEST

The FY 1991 Request for the Engineering Infrastructure Development (EID) Subactivity is $25.43 million, an increase of $8.61 million, or 51.2 percent, over the FY 1990 Current Plan of $16.82 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Engineering Education	$1.70	$6.00	$6.00	$12.00
Human Resources Development	4.22	4.63	6.52	8.93
Physical Infrastructure Development	3.26	3.52	2.47	2.50
Special Studies and Analyses	1.44	1.85	1.83	2.00
Total, Subactivity	$10.62	$16.00	$16.82	$25.43

SCIENTIFIC OVERVIEW

The EID Subactivity supports and coordinates within ENG activities to strengthen the Nation's engineering infrastructure, including education, human resources, instrumentation and facilities. EID programs are focused upon developing the quality of engineering professionals essential to continuously improving the competitive position of the United States.

EID supports targeted programs which strengthen the quality and effectiveness of engineering educational programs, increase the number and quality of engineering students and faculty, improve instructional and research equipment and facilities, and encourage international relationships to improve engineering education and research.

EID provides funding for important cross-disciplinary studies that deal with issues and opportunities, both national and international, facing the engineering academic community and the engineering profession.

The EID Subactivity seeks to:

- Increase the effectiveness of engineering education through curriculum revision, instructional development, and strengthened laboratory experiences.
- Increase the number and quality of engineering professionals available for the next decade by expanding the number of minorities, women, and disabled individuals participating in

engineering education and research. This includes broadening efforts in predominantly undergraduate institutions.

- Recognize the critical importance of specialized research and instructional equipment by supporting its acquisition.
- Promote cross-disciplinary activities that will advance U.S. engineering through international cooperation.

In carrying out its objectives, EID works closely with other elements of ENG and with other NSF Activities, such as SEE and STIA. Within the ENG Activity, EID provides essential leadership and coordination while the other Subactivities provide disciplinary expertise and a research focus. EID also coordinates the participation of ENG in many cross-directorate programs, such as Research Experiences for Undergraduates (REU) and Research Opportunities for Women (ROW).

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Engineering Education	$1.70	$6.00	$6.00	$0.00	0.0%
Human Resources Development	4.22	4.63	6.52	1.89	40.8
Physical Infrastructure Development	3.26	3.52	2.47	-1.05	-29.8
Special Studies and Analyses	1.44	1.85	1.83	-0.02	-1.1
Total, Subactivity	$10.62	$16.00	$16.82	$0.82	5.1%

The FY 1990 Current Plan is $16.82 million, which is an increase of $0.82 million, or 5.1 percent, over the FY 1990 Budget Request of $16.00 million. This is a 6.20 million, or 58.4 percent increase over FY 1989. This increase significantly expands support for undergraduate engineering education and for women and minority graduate students, both very high priorities for the ENG Activity. Major emphasis is being given to developing multi-university coalitions which will evaluate and disseminate new approaches in undergraduate engineering education. Also in FY 1990, new traineeships and fellowships for women and minority engineering graduate students are supported in order to increase the number of women and minorities in engineering Ph.D programs in the United States.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Engineering Education	$6.00	$12.00	$6.00	100.0%
Human Resources Development	6.52	8.93	2.41	37.0
Physical Infrastructure Development	2.47	2.50	0.03	1.2
Special Studies and Analyses	1.83	2.00	0.17	9.3
Total, Subactivity	$16.82	$25.43	$8.61	51.2%

The $8.61 million increase in the FY 1991 Request, to a total of $25.43 million, represents a 51.2 percent increase over the FY 1990 Current Plan of $16.82 million. This provides:

- An increase of $5.00 million, to $11.00 million, to fund two new engineering education coalitions, bringing the total number funded by NSF to five. These coalitions are aimed at dramatically increasing the quality of undergraduate engineering education by designing, implementing, evaluating and disseminating new teaching structures, approaches and technologies. The coalitions aim to create strong linkages and intellectual exchanges between U.S. engineering schools and increase the number of degrees awarded to women and minorities. ENG will work with the SEE Directorate, which is providing an additional $4.00 million for this effort, to evaluate research results and models.
- $1.00 million in new funding to support pilot projects aimed at developing model undergraduate engineering courses and laboratories at the introductory level, and promoting the introduction of new teaching technologies.
- An increase of $2.41 million, from $6.52 to $8.93 million, for Human Resources Development. Special NSF-wide programs to expand the participation of undergraduate women and minorities in engineering research will be supported, such as the new Alliances for Minority Participation program, which will encourage undergraduate minority students to pursue graduate studies. Also, $0.50 million will be used to increase the number of graduate fellowships for women engineering students. The total number supported by NSF in FY 1991 will be 160 students; 80 by the ENG Activity and 80 by the SEE Activity.
- A $0.17 million increase, to $2.00 million, is requested for Special Studies and Analyses, to initiate studies, workshops and conferences to promote the participation of women and minorities in engineering.
- A slight increase is requested for Physical Infrastructure Development, from $2.47 to $2.50 million, to fund matching instrumentation grants that will improve the quality of the engineering research and education.

CHANGES IN BUDGET STRUCTURE

Th Engineering Infrastructure Development (EID) Subactivity was established in FY 1990 to provide a stronger management focus for ENG support of engineering education, special equipment and instrumentation, and programs to develop human resources.

Prior to this restructuring, many of EID's activities were funded by contributions from the other ENG Subactivities and managed by ENG's Office of Engineering Infrastructure Development. As shown in the ENG Activity Crosswalk Table at the end of the ENG Activity Summary, a total of $16.82 million was transferred from the other ENG Subactivities to provide for EID's FY 1990 Current Plan.

EID also coordinates the ENG participation in many of the Foundation's cross-directorate programs, such as Research Experiences for Undergraduates (REU) and Research Opportunities for Women (ROW).

year old R/V CONRAD with the R/V BERNIER to provide enhanced capabilities for marine geology and geophysics field programs including multichannel seismic studies.

The Ocean Drilling Program supports research and operations of the international Ocean Drilling Program. The goal of the program is to improve understanding of the composition, history and processes affecting the sea floor, and to improve resource and climate prediction. For example, sediments and volcanic rock samples recovered from the Sea of Japan and island chains south of Japan document periods of variable explosive volcanic activity. The results provide new time controls for understanding the history and mechanisms of geologic change and variations in natural hazards in the region.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Ocean Sciences Research Support	$70.92	$74.66	$72.93	$-1.73	-2.3%
Oceanographic Centers and Facilities	43.59	45.33	42.46	-2.87	-6.3
Ocean Drilling Program	31.38	32.89	31.98	-0.91	-2.8
Total, Subactivity	$145.88	$152.88	$147.37	$-5.51	-3.6%

The FY 1990 Current Plan for Ocean Sciences is $147.37 million, a decrease of $5.51 million, or 3.6 percent, from the FY 1990 Budget Request, but an increase of $1.49 million, or 1.0 percent, over FY 1989.

Global Geosciences activities will be held at the Request level per Congressional directive, less the across-the-board reductions. Other activities will absorb a proportionate share of unspecified Congressional reductions. The number of individual grants will be reduced, as will funding for large multi-investigator projects. Increased operational costs for the Ocean Drilling Program will be met by adjustments in support for field studies. Operational support provided to the academic research fleet will be reduced and several research vessels will be delayed in returning to service after refits.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Ocean Sciences Research Support	$72.93	$88.58	$15.65	21.5%
Oceanographic Centers and Facilities	42.46	47.44	4.98	11.7
Ocean Drilling Program	31.98	34.98	3.00	9.4
Total, Subactivity	$147.37	$171.00	$23.63	16.0%

The FY 1991 Budget Request is $171.00 million, an increase of $23.63 million, or 16.0 percent, above the FY 1990 Current Plan level of $147.37 million.

Global Geosciences programs will receive an increment of $19.20 million, and other programs will be increased by $4.43 million in order to maintain essential components upon which new thrusts are built.

OCEAN SCIENCES RESEARCH SUPPORT

This program element seeks to improve understanding of the ocean and how it behaves. Research is aimed at determining how the ocean and atmosphere interact; the influence of the ocean on weather and global climate; the impact of global climate change on marine ecosystems and the transport and recycling of materials such as CO2; and dispersal of wastes. This research will extend the scientific understanding of important phenomena of significant societal concern. Examples are plate tectonics processes which are important for improved understanding of earthquakes; ocean control of atmospheric CO2 for understanding of greenhouse warming; and ocean/atmosphere interactions for understanding of El Niño, hurricanes, and droughts.

Ocean Sciences Research Support increases by $15.65 million, or 21.5 percent, to $88.58 million. Research support increases will focus on global change, through interdisciplinary ocean studies which form major components of the NSF Global Geosciences program. Noteworthy are:

- implementation of the World Ocean Circulation Experiment (WOCE) will continue with hydrographic sections of the Pacific, initiation of the surface drifter program, and Atlantic process experiments;
- expansion of the Joint Global Ocean Flux Study (JGOFS) with a Pacific equatorial biogeochemical flux field program;
- initiation of a Ridge Interdisciplinary Global Experiment (RIDGE) field program on the East-Pacific rise;
- participation in the Tropical Ocean/Global Atmosphere-Coupled Ocean/Atmosphere Response Experiment (TOGA-COARE); and

- long lead-time instrumentation and model development for the Global Ocean Ecosystem Dynamics program (GLOBEC).

OCEANOGRAPHIC CENTERS AND FACILITIES

This program element supports research at sea by providing ships and other shared-use facilities required by NSF grantees. Included are operations and maintenance of research ships and the deep submergence research vehicle ALVIN, support of technicians to maintain and operate shipboard scientific systems, and support for the University-National Oceanographic Laboratory System Office to schedule ship use. In FY 1990, NSF provided about 75 percent of the funds required for academic fleet operations. Support also comes from the Office of Naval Research, state governments, and private sources.

This program element also provides support for acquiring and developing shared use instruments and equipment. Adaptation of existing technologies to ocean sciences and development of new instruments is included. Ship design studies and conversion and upgrading of ships and other platforms are supported as required to meet research needs.

Funding for Oceanographic Centers and Facilities increases by $4.98 million, to $47.44 million, focused on facilities and field operations, and on technological requirements of the Global Geosciences Program, including:

- ship and technical support for the Global Geosciences field programs funded by the ocean sciences research program;
- ocean technology support for new *in-situ* instruments for ecosystems dynamics sampling systems, and operations of the accelerator mass spectrometry facility; and
- modification and upgrading of scientific support equipment in the academic research fleet to meet data requirements of the global change research programs.

OCEAN DRILLING PROGRAM

The Ocean Drilling Program Element (ODP) supports studies of ocean basins using drilling techniques to sample oceanic crust and sediment deposits.

Funding by the U.S. and its international partners in the ODP supports drilling operations and associated logistic and scientific services. International members of the ODP are France, Federal Republic of Germany, United Kingdom, Japan, the European Science Foundation (representing a consortium of 12 European countries), and a consortium representing Canada and Australia. Joint operations include shipboard and shore-based laboratories; core repositories and associated data banks containing samples and records; an engineering development program for drilling technology; and a center to develop and operate down-hole logging instruments.

U.S. support for ODP operations will increase in FY 1991 by $1.60 million from $21.50 million to $23.10 million to cover inflationary increases in drilling-related activities and for development of crustal drilling technology. International contributions increased from $15.00 million in FY 1989 to $16.50 million in FY 1990, and will remain at that level in FY 1991.

Each country participating in the ODP sponsors related research carried out by its scientific community. NSF supports regional studies of potential drill sites, shipboard participation of U.S. scientists, data analysis, design and use of shipboard and down-hole experiments, and workshops, symposia and planning activities. Support for research within ODP increases by $1.40 million to $11.88 million, with emphasis on:

- development and use of measurement and sampling tools for high temperature ridge-crest environments;
- design and development of experiments to measure crustal deformation and fluid flow in boreholes;
- high latitude field programs to define the regional geologic framework for future drilling programs; and
- increased support for analysis of geochemical and geophysical logging data.

ARCTIC RESEARCH PROGRAM $16,650,000

SUMMARY OF REQUEST

The FY 1991 Budget Request for the Arctic Research Program is $16.65 million, an increase of $4.20 million, or 33.7 percent, over the FY 1990 Current Plan of $12.45 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Arctic Research Projects	$9.78	$12.32	$11.96	$16.14
Arctic Research Commission	0.50	0.50	0.49	0.51
Total, Subactivity	$10.28	$12.82	$12.45	$16.65

SCIENTIFIC OVERVIEW

The goal of the Arctic Research Program Subactivity is to increase knowledge of the arctic region and to extract the information it can provide concerning the global environment. The Arctic is comprised of the Arctic Ocean and the surrounding land masses, including part of Alaska. Scientific interest in the Arctic stretches from the ocean bottom through the ice cover and into space, where the interaction of solar radiation with the earth's atmosphere begins. Research also involves arctic land areas and their people, plants and wildlife. Areas of interest include atmospheric, biological, earth and ocean sciences, and glaciology. This research is relevant to weather, climate and environmental protection. The intended results include better prediction of arctic phenomena and a more intelligent extension of human activity to the Arctic, especially in regions of practical importance to the United States, such as Alaska.

As required by the Arctic Research and Policy Act of 1984, an interagency committee chaired by the NSF Director continues its planning and coordination activities. These have included a recent revision of the United States Arctic Research Plan, which was delivered to Congress August 1, 1989, and published in the Fall, 1989 issue of *Arctic Research of the United States*. The plan, which is required by the Act, includes recommendations for future programs. The Arctic Research Commission, also established pursuant to the Act, continues its specified efforts. As an independent federal body, the Commission provides policy recommendations to the President and the Congress.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Arctic Research Projects	$9.78	$12.32	$11.96	$-0.36	-2.9%
Arctic Research Commission	0.50	0.50	0.49	-0.01	-3.0
Total, Subactivity	$10.28	$12.82	$12.45	$-0.37	-2.9%

The FY 1990 Current Plan is $12.45 million, a decrease of $0.37 million, or 2.9 percent, from the FY 1990 Budget Request of $12.82 million, but an increase of $2.17 million, or 21.1 percent, over FY 1989. The decrease results from Congressionally mandated reductions.

The increase of $2.17 million will be used for the Arctic Systems Sciences program, an element of the Global Geosciences Program.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Arctic Research Projects	$11.96	$16.14	$4.18	34.9%
Arctic Research Commission	0.49	0.51	0.02	5.2
Total, Subactivity	$12.45	$16.65	$4.20	33.7%

The FY 1991 Budget Request is $16.65 million, an increase of $4.20 million, or 33.7 percent, above the FY 1990 Current Plan level of $12.45 million.

ARCTIC RESEARCH PROJECTS

Research projects supported by the Arctic Research Program include northern components of bipolar investigations. The importance of bipolar studies is particularly relevant in the disciplines of glaciology and upper atmospheric physics. Such work contributes to the understanding of global phenomena. The southern portion is supported under the U.S. Antarctic Program. Additional funding for arctic studies is included in other NSF subactivities. The research being undertaken and planned is in line with recommendations of the Arctic Research Commission and the Interagency Arctic Research Policy Committee (IARPC).

Of the increase of $4.18 million, $1.00 million will be used to initiate an Arctic Social Sciences program, a response to recommendations by the Arctic Research Commission, the IARPC, the National Science Board, the National Academy of Science and Congress. The balance of the increase will go toward the Arctic Systems Sciences (ARCSS) program, which focuses on environmental change in the Arctic. Paleoclimate studies from ice sheets are a key part of this effort.

A Greenland ice-coring project is under way that is expected to provide a detailed climate record for over 100,000 years that is unobtainable by other means. Paleoclimate studies and investigations of modern environmental processes are essential for global climate forecasts. The ice coring project will receive an increment of $0.50 million.

An additional $2.68 million will be used for coordinated interdisciplinary research on arctic ocean, sea ice and atmospheric interactions and to support smaller scale studies on arctic terrestrial ecosystems and biogeochemical cycles. These complementary projects are aimed at providing increased understanding of arctic systems and how they may respond to and cause climate change.

ARCTIC RESEARCH COMMISSION

The FY 1991 Budget Request will permit the Arctic Research Commission to continue its activities. Funding is provided for administrative costs of staff, office space, travel, and consultants. Funds are provided through NSF as a matter of budgetary convenience.

Science and Technology Centers $4,425,000

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $4.43 million, an increase of $3.45 million, or 351.5% percent, over the FY 1990 Current Plan of $0.98 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$0.94	$1.00	$0.98	$4.43

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

One of the eleven centers, funded in February 1989, is in the Geosciences Activity, and this investment has already achieved impressive results. For example, the Center for Analysis and Prediction of Storms has successfully used methods with an atmospheric prediction model that increases details only in those areas of the model where large changes are occurring. This is critical since computers currently do not have sufficient power to provide highly detailed information over an entire region of the U.S. This is an important accomplishment which may eventually lead to improving regional productions of severe weather.

CHANGES BETWEEN FY199O REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Science and Technology Centers	$0.94	$1.00	$0.98	$-0.02	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and the mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Science and Technology Centers	$0.98	$4.43	$3.45	351.5%

The FY 1991 Budget Request for STC's in the GEO Activity is $4.43 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial GEO STC called for modest increases to bring the center up to full operational levels. That objective could not be fully met in 1990 due to across-the-board reduction to the Subactivity; the existing center will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

MATHEMATICAL AND PHYSICAL SCIENCES........................$621,500,000

SUMMARY OF REQUEST

The FY 1991 Request for Mathematical and Physical Sciences (MPS) is $621.50 million, an increase of $64.49 million, or 11.6 percent, over the FY 1990 Current Plan of $557.01 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Mathematical Sciences	$66.02	$76.05	$69.12	$73.72
Astronomical Sciences	89.22	94.02	91.65	100.70
Physics	122.28	130.00	123.83	130.23
Chemistry	96.75	103.43	97.94	103.35
Materials Research	115.08	123.18	116.94	123.46
Science and Technology Centers	13.95	14.83	14.54	27.04
Major Research Equipment	0.50	12.00	42.99	63.00
Total, Activity	$503.80	$553.50	$557.01*	$621.50

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

NSF ROLE

The Mathematical and Physical Sciences Activity supports research that develops an understanding of the physical laws governing the world in which we live. Similarly, research in mathematics, astronomy, physics, chemistry and materials science establishes the knowledge base for future technological developments upon which our economic and social well-being depend, simultaneously providing the training for the next generation of scientists.

MPS supports individual and group research, special instrumentation, university research laboratories, and national user facilities. Support is focused in colleges and universities because they combine forefront research with advanced training of graduate students. Except for mathematics, MPS disciplines involve experimental and observational research, which requires an adequate instrumental capability. Thus, MPS emphasizes provision of modern research equipment, together with the associated technical support and necessary maintenance.

The 1989 Nobel Prize in Physics was shared, in part, by two scientists supported by the NSF through the Physics Subactivity. Both Professor Hans Dehmelt of the University of Washington and Professor Norman Ramsey of Harvard University have carried out research in precision measurements using the techniques of atomic physics. Their work has benefitted from the long-term, sustained support which is possible through the basic research programs of the Foundation.

Some fields of research also require centralized, major research instrumentation. Consequently, support is provided for a variety of university laboratories, including accelerator laboratories in nuclear physics and interdisciplinary Materials Research Laboratories.

National user facilities also are maintained to provide major experimental or intellectual resources available to the broad scientific community. These include three accelerator facilities for experiments in high energy and nuclear physics; three astronomy centers; facilities for materials research using synchrotron radiation and high magnetic fields; and research institutes in both mathematics and theoretical physics.

Research in the mathematical and physical sciences is increasingly interactive in character, with results in one area having important applications to research in other areas. For example, observance of chaotic behavior in dynamical (changing) systems has led to a virtual explosion of new mathematical research in analysis, applied mathematics and probability. It has raised deep, fundamental questions on the predictability of behavior and the effects of randomness. This research on "chaos" cuts across several traditional scientific boundaries, providing a fresh look at the seemingly irregular and complex phenomena observed in nature such as weather patterns, fluid dynamics, and population dynamics.

This modern trend toward increased interaction among scientific disciplines is further illustrated by ongoing programs on the chemistry of life processes, materials chemistry, and materials processing. The broad field of materials research is inherently multidisciplinary, deriving much of its vitality from contributions by a variety of scientific and engineering sub-disciplines.

Use of advanced computers as an adjunct to theoretical and experimental research is continuing to increase in importance. New insights and approaches are possible in the mathematical and physical sciences as a result of advances in computing, mathematical modeling, and algorithm development. MPS disciplines played a key role in many of these developments and will continue to play critical roles in the future.

Human resources remain a major concern of the MPS disciplines. In addition to the traditional support of graduate students and postdoctoral research associates, the disciplines emphasize research experience for undergraduate students, undergraduate curriculum development, and mentoring programs for women and minorities.

Other federal agencies also support academic research in the MPS disciplines, but in contrast to NSF, they focus on areas of mission relevance. MPS coordinates its funding with other agencies in a way that guards the overall health of U.S. science. Every effort is made to maintain the continuity and the broad support base of the research and yet avoid blunting planned mission agency emphases. NSF provides 44 percent of the total Federal support for academic-based research in the MPS disciplines.

Typically, coordination with other agencies is carried out through interagency coordinating committees. Each MPS Subactivity has participants on such committees, which consist of program officials from all relevant federal agencies. The larger programs, however, require more extensive and formal approaches to interagency coordination. Planning and coordination in elementary particle physics are carried out in the Department of Energy (DOE) High Energy Physics Advisory Panel (HEPAP), in which NSF actively participates. In nuclear science, this function is performed by the joint NSF-DOE Nuclear Science Advisory Committee (NSAC).

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Mathematical Sciences	$66.02	$76.05	$69.12	$-6.93	-9.1%
Astronomical Sciences	89.22	94.02	91.65	-2.37	-2.5
Physics	122.28	130.00	123.83	-6.17	-4.7
Chemistry	96.75	103.43	97.94	-5.49	-5.3
Materials Research	115.08	123.18	116.94	-6.24	-5.1
Science and Technology Centers	13.95	14.83	14.54	-0.29	-2.0
Major Research Equipment	0.50	12.00	42.99	30.99	258.3
Total, Activity	$503.80	$553.50	$557.01*	$3.51	0.6%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

The FY 1990 Current Plan is $557.01 million, an increase of $3.51 million, or 0.6 percent, above the FY 1990 Budget Request. This increase is the net of Congressionally mandated reductions to the total request, offset by supplemental FY 1990 funds provided by Congress for replacement of the Green Bank Telescope (GBT). Additional unobligated FY 1989 funds are also available for the GBT.

Within the FY 1990 allocation, priority is given to Astronomical Sciences and to undergraduate curriculum development in Mathematical Sciences, Physics, and Chemistry. Other priorities are maintained at a lower level of growth.

A new Subactivity, Major Research Equipment, is established, including the Green Bank Telescope from Astronomical Sciences and the National High Magnetic Field Laboratory from Materials Research.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Mathematical Sciences	$69.12	$73.72	$4.60	6.7%
Astronomical Sciences	91.65	100.70	9.05	9.9
Physics	123.83	130.23	6.40	5.2
Chemistry	97.94	103.35	5.41	5.5
Materials Research	116.94	123.46	6.52	5.6
Science and Technology Centers	14.54	27.04	12.50	86.0
Major Research Equipment	42.99	63.00	20.01	46.5
Total, Activity	$557.01*	$621.50	$64.49	11.6%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank telescope, which is available in FY 1990.

The MPS Activity is increased by $64.49 million or 11.6 percent over the FY 1990 Current Plan, for a total of $621.5 million. The FY 1991 Request incorporates the Foundation's two central budget themes. The major emphasis in the FY 1991 Request is on instrumentation and human resources in order to help assure the future vitality of the MPS disciplines.

RESEARCH AND FACILITIES:

The FY 1991 request includes over $575 million for research and facilities, an increase of more than $52 million over FY 1990 levels.

- Two new major equipment projects are planned to provide unique research facilities: the Laser Interferometer Gravitational Wave Observatory and two 8-meter Optical/Infrared Telescopes. An increase of $20.01 million in the Major Research Equipment Subactivity is provided to initiate these projects, which involve substantial international cooperation.
- New technology in antenna design permits the performance of the 305-meter diameter reflector at the Arecibo Observatory to be improved significantly at modest cost. $5.0 million is requested to begin this project. The estimated cost over two years is $22.0 million, of which NASA will contribute 50 percent.
- Support for other equipment and instrumentation increases by about $10.0 million to a total in FY 1991 of over $94.0 million. In all, support for instrumentation and major equipment represents over 18 percent of the FY 1991 request.
- Support continues for the six Science and Technology Centers established in FY 1989, and an additional $12.5 million is included for new Science and Technology Centers to be

awarded as a result of the second competition held in FY 1990. The Howard University Minority Research Center of Excellence in materials research will be transferred to MPS.

- Support for graduate research assistants will increase by over $4.0 million to bring the MPS total to more than $58 million, for almost 5700 students.

Within the ongoing program a partial upgrade of the ultra-high energy cosmic ray detector (Fly's Eye) will begin. Focus on superconductivity research is maintained at the FY 1990 level of $24.1 million. Construction of the Very Long Baseline Array radio telescope continues, with completion planned for FY 1993.

EDUCATION AND HUMAN RESOURCES:

The FY 1991 request includes nearly $46 million for support of education and human resources, an increase of $12 million over the FY 1990 levels.

- Support for new investigators will be augmented by $4.8 million to fund 60 new research awards in emerging areas. This emphasis is in addition to new awards for Presidential Young Investigators.
- Strong undergraduate efforts will continue, including expanded course and curriculum development at the introductory level and Research Experiences for Undergraduates with an enhanced emphasis on mentorship. In all, support for undergraduate activities will increase more than $5.5 million, to over $18 million.
- Funds are also provided for new Foundation-wide activities to increase the participation of women and minorities in science and engineering.

CHANGES IN BUDGET STRUCTURE

The Major Research Equipment Subactivity was established in FY 1990 for new large scale construction projects.

year old R/V CONRAD with the R/V BERNIER to provide enhanced capabilities for marine geology and geophysics field programs including multichannel seismic studies.

The Ocean Drilling Program supports research and operations of the international Ocean Drilling Program. The goal of the program is to improve understanding of the composition, history and processes affecting the sea floor, and to improve resource and climate prediction. For example, sediments and volcanic rock samples recovered from the Sea of Japan and island chains south of Japan document periods of variable explosive volcanic activity. The results provide new time controls for understanding the history and mechanisms of geologic change and variations in natural hazards in the region.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Ocean Sciences Research Support	$70.92	$74.66	$72.93	$-1.73	-2.3%
Oceanographic Centers and Facilities ..	43.59	45.33	42.46	-2.87	-6.3
Ocean Drilling Program	31.38	32.89	31.98	-0.91	-2.8
Total, Subactivity	$145.88	$152.88	$147.37	$-5.51	-3.6%

The FY 1990 Current Plan for Ocean Sciences is $147.37 million, a decrease of $5.51 million, or 3.6 percent, from the FY 1990 Budget Request, but an increase of $1.49 million, or 1.0 percent, over FY 1989.

Global Geosciences activities will be held at the Request level per Congressional directive, less the across-the-board reductions. Other activities will absorb a proportionate share of unspecified Congressional reductions. The number of individual grants will be reduced, as will funding for large multi-investigator projects. Increased operational costs for the Ocean Drilling Program will be met by adjustments in support for field studies. Operational support provided to the academic research fleet will be reduced and several research vessels will be delayed in returning to service after refits.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Ocean Sciences Research Support	$72.93	$88.58	$15.65	21.5%
Oceanographic Centers and Facilities	42.46	47.44	4.98	11.7
Ocean Drilling Program	31.98	34.98	3.00	9.4
Total, Subactivity	$147.37	$171.00	$23.63	16.0%

The FY 1991 Budget Request is $171.00 million, an increase of $23.63 million, or 16.0 percent, above the FY 1990 Current Plan level of $147.37 million.

Global Geosciences programs will receive an increment of $19.20 million, and other programs will be increased by $4.43 million in order to maintain essential components upon which new thrusts are built.

OCEAN SCIENCES RESEARCH SUPPORT

This program element seeks to improve understanding of the ocean and how it behaves. Research is aimed at determining how the ocean and atmosphere interact; the influence of the ocean on weather and global climate; the impact of global climate change on marine ecosystems and the transport and recycling of materials such as CO2; and dispersal of wastes. This research will extend the scientific understanding of important phenomena of significant societal concern. Examples are plate tectonics processes which are important for improved understanding of earthquakes; ocean control of atmospheric CO2 for understanding of greenhouse warming; and ocean/atmosphere interactions for understanding of El Niño, hurricanes, and droughts.

Ocean Sciences Research Support increases by $15.65 million, or 21.5 percent, to $88.58 million. Research support increases will focus on global change, through interdisciplinary ocean studies which form major components of the NSF Global Geosciences program. Noteworthy are:

- implementation of the World Ocean Circulation Experiment (WOCE) will continue with hydrographic sections of the Pacific, initiation of the surface drifter program, and Atlantic process experiments;
- expansion of the Joint Global Ocean Flux Study (JGOFS) with a Pacific equatorial biogeochemical flux field program;
- initiation of a Ridge Interdisciplinary Global Experiment (RIDGE) field program on the East-Pacific rise;
- participation in the Tropical Ocean/Global Atmosphere-Coupled Ocean/Atmosphere Response Experiment (TOGA-COARE); and

- long lead-time instrumentation and model development for the Global Ocean Ecosystem Dynamics program (GLOBEC).

OCEANOGRAPHIC CENTERS AND FACILITIES

This program element supports research at sea by providing ships and other shared-use facilities required by NSF grantees. Included are operations and maintenance of research ships and the deep submergence research vehicle ALVIN, support of technicians to maintain and operate shipboard scientific systems, and support for the University-National Oceanographic Laboratory System Office to schedule ship use. In FY 1990, NSF provided about 75 percent of the funds required for academic fleet operations. Support also comes from the Office of Naval Research, state governments, and private sources.

This program element also provides support for acquiring and developing shared use instruments and equipment. Adaptation of existing technologies to ocean sciences and development of new instruments is included. Ship design studies and conversion and upgrading of ships and other platforms are supported as required to meet research needs.

Funding for Oceanographic Centers and Facilities increases by $4.98 million, to $47.44 million, focused on facilities and field operations, and on technological requirements of the Global Geosciences Program, including:

- ship and technical support for the Global Geosciences field programs funded by the ocean sciences research program;
- ocean technology support for new *in-situ* instruments for ecosystems dynamics sampling systems, and operations of the accelerator mass spectrometry facility; and
- modification and upgrading of scientific support equipment in the academic research fleet to meet data requirements of the global change research programs.

OCEAN DRILLING PROGRAM

The Ocean Drilling Program Element (ODP) supports studies of ocean basins using drilling techniques to sample oceanic crust and sediment deposits.

Funding by the U.S. and its international partners in the ODP supports drilling operations and associated logistic and scientific services. International members of the ODP are France, Federal Republic of Germany, United Kingdom, Japan, the European Science Foundation (representing a consortium of 12 European countries), and a consortium representing Canada and Australia. Joint operations include shipboard and shore-based laboratories; core repositories and associated data banks containing samples and records; an engineering development program for drilling technology; and a center to develop and operate down-hole logging instruments.

U.S. support for ODP operations will increase in FY 1991 by $1.60 million from $21.50 million to $23.10 million to cover inflationary increases in drilling-related activities and for development of crustal drilling technology. International contributions increased from $15.00 million in FY 1989 to $16.50 million in FY 1990, and will remain at that level in FY 1991.

Each country participating in the ODP sponsors related research carried out by its scientific community. NSF supports regional studies of potential drill sites, shipboard participation of U.S. scientists, data analysis, design and use of shipboard and down-hole experiments, and workshops, symposia and planning activities. Support for research within ODP increases by $1.40 million to $11.88 million, with emphasis on:

- development and use of measurement and sampling tools for high temperature ridge-crest environments;
- design and development of experiments to measure crustal deformation and fluid flow in boreholes;
- high latitude field programs to define the regional geologic framework for future drilling programs; and
- increased support for analysis of geochemical and geophysical logging data.

ARCTIC RESEARCH PROGRAM $16,650,000

SUMMARY OF REQUEST

The FY 1991 Budget Request for the Arctic Research Program is $16.65 million, an increase of $4.20 million, or 33.7 percent, over the FY 1990 Current Plan of $12.45 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Arctic Research Projects	$9.78	$12.32	$11.96	$16.14
Arctic Research Commission	0.50	0.50	0.49	0.51
Total, Subactivity	$10.28	$12.82	$12.45	$16.65

SCIENTIFIC OVERVIEW

The goal of the Arctic Research Program Subactivity is to increase knowledge of the arctic region and to extract the information it can provide concerning the global environment. The Arctic is comprised of the Arctic Ocean and the surrounding land masses, including part of Alaska. Scientific interest in the Arctic stretches from the ocean bottom through the ice cover and into space, where the interaction of solar radiation with the earth's atmosphere begins. Research also involves arctic land areas and their people, plants and wildlife. Areas of interest include atmospheric, biological, earth and ocean sciences, and glaciology. This research is relevant to weather, climate and environmental protection. The intended results include better prediction of arctic phenomena and a more intelligent extension of human activity to the Arctic, especially in regions of practical importance to the United States, such as Alaska.

As required by the Arctic Research and Policy Act of 1984, an interagency committee chaired by the NSF Director continues its planning and coordination activities. These have included a recent revision of the United States Arctic Research Plan, which was delivered to Congress August 1, 1989, and published in the Fall, 1989 issue of *Arctic Research of the United States*. The plan, which is required by the Act, includes recommendations for future programs. The Arctic Research Commission, also established pursuant to the Act, continues its specified efforts. As an independent federal body, the Commission provides policy recommendations to the President and the Congress.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Arctic Research Projects	$9.78	$12.32	$11.96	$-0.36	-2.9%
Arctic Research Commission	0.50	0.50	0.49	-0.01	-3.0
Total, Subactivity	$10.28	$12.82	$12.45	$-0.37	-2.9%

The FY 1990 Current Plan is $12.45 million, a decrease of $0.37 million, or 2.9 percent, from the FY 1990 Budget Request of $12.82 million, but an increase of $2.17 million, or 21.1 percent, over FY 1989. The decrease results from Congressionally mandated reductions.

The increase of $2.17 million will be used for the Arctic Systems Sciences program, an element of the Global Geosciences Program.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Arctic Research Projects	$11.96	$16.14	$4.18	34.9%
Arctic Research Commission	0.49	0.51	0.02	5.2
Total, Subactivity	$12.45	$16.65	$4.20	33.7%

The FY 1991 Budget Request is $16.65 million, an increase of $4.20 million, or 33.7 percent, above the FY 1990 Current Plan level of $12.45 million.

ARCTIC RESEARCH PROJECTS

Research projects supported by the Arctic Research Program include northern components of bipolar investigations. The importance of bipolar studies is particularly relevant in the disciplines of glaciology and upper atmospheric physics. Such work contributes to the understanding of global phenomena. The southern portion is supported under the U.S. Antarctic Program. Additional funding for arctic studies is included in other NSF subactivities. The research being undertaken and planned is in line with recommendations of the Arctic Research Commission and the Interagency Arctic Research Policy Committee (IARPC).

Of the increase of $4.18 million, $1.00 million will be used to initiate an Arctic Social Sciences program, a response to recommendations by the Arctic Research Commission, the IARPC, the National Science Board, the National Academy of Science and Congress. The balance of the increase will go toward the Arctic Systems Sciences (ARCSS) program, which focuses on environmental change in the Arctic. Paleoclimate studies from ice sheets are a key part of this effort.

A Greenland ice-coring project is under way that is expected to provide a detailed climate record for over 100,000 years that is unobtainable by other means. Paleoclimate studies and investigations of modern environmental processes are essential for global climate forecasts. The ice coring project will receive an increment of $0.50 million.

An additional $2.68 million will be used for coordinated interdisciplinary research on arctic ocean, sea ice and atmospheric interactions and to support smaller scale studies on arctic terrestrial ecosystems and biogeochemical cycles. These complementary projects are aimed at providing increased understanding of arctic systems and how they may respond to and cause climate change.

ARCTIC RESEARCH COMMISSION

The FY 1991 Budget Request will permit the Arctic Research Commission to continue its activities. Funding is provided for administrative costs of staff, office space, travel, and consultants. Funds are provided through NSF as a matter of budgetary convenience.

Science and Technology Centers $4,425,000

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $4.43 million, an increase of $3.45 million, or 351.5% percent, over the FY 1990 Current Plan of $0.98 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$0.94	$1.00	$0.98	$4.43

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

One of the eleven centers, funded in February 1989, is in the Geosciences Activity, and this investment has already achieved impressive results. For example, the Center for Analysis and Prediction of Storms has successfully used methods with an atmospheric prediction model that increases details only in those areas of the model where large changes are occurring. This is critical since computers currently do not have sufficient power to provide highly detailed information over an entire region of the U.S. This is an important accomplishment which may eventually lead to improving regional productions of severe weather.

CHANGES BETWEEN FY199O REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Science and Technology Centers	$0.94	$1.00	$0.98	$-0.02	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and the mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Science and Technology Centers	$0.98	$4.43	$3.45	351.5%

The FY 1991 Budget Request for STC's in the GEO Activity is $4.43 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial GEO STC called for modest increases to bring the center up to full operational levels. That objective could not be fully met in 1990 due to across-the-board reduction to the Subactivity; the existing center will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

MATHEMATICAL AND PHYSICAL SCIENCES........................$621,500,000

SUMMARY OF REQUEST

The FY 1991 Request for Mathematical and Physical Sciences (MPS) is $621.50 million, an increase of $64.49 million, or 11.6 percent, over the FY 1990 Current Plan of $557.01 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Mathematical Sciences	$66.02	$76.05	$69.12	$73.72
Astronomical Sciences	89.22	94.02	91.65	100.70
Physics	122.28	130.00	123.83	130.23
Chemistry	96.75	103.43	97.94	103.35
Materials Research	115.08	123.18	116.94	123.46
Science and Technology Centers	13.95	14.83	14.54	27.04
Major Research Equipment	0.50	12.00	42.99	63.00
Total, Activity	$503.80	$553.50	$557.01*	$621.50

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

NSF ROLE

The Mathematical and Physical Sciences Activity supports research that develops an understanding of the physical laws governing the world in which we live. Similarly, research in mathematics, astronomy, physics, chemistry and materials science establishes the knowledge base for future technological developments upon which our economic and social well-being depend, simultaneously providing the training for the next generation of scientists.

MPS supports individual and group research, special instrumentation, university research laboratories, and national user facilities. Support is focused in colleges and universities because they combine forefront research with advanced training of graduate students. Except for mathematics, MPS disciplines involve experimental and observational research, which requires an adequate instrumental capability. Thus, MPS emphasizes provision of modern research equipment, together with the associated technical support and necessary maintenance.

The 1989 Nobel Prize in Physics was shared, in part, by two scientists supported by the NSF through the Physics Subactivity. Both Professor Hans Dehmelt of the University of Washington and Professor Norman Ramsey of Harvard University have carried out research in precision measurements using the techniques of atomic physics. Their work has benefitted from the long-term, sustained support which is possible through the basic research programs of the Foundation.

Some fields of research also require centralized, major research instrumentation. Consequently, support is provided for a variety of university laboratories, including accelerator laboratories in nuclear physics and interdisciplinary Materials Research Laboratories.

National user facilities also are maintained to provide major experimental or intellectual resources available to the broad scientific community. These include three accelerator facilities for experiments in high energy and nuclear physics; three astronomy centers; facilities for materials research using synchrotron radiation and high magnetic fields; and research institutes in both mathematics and theoretical physics.

Research in the mathematical and physical sciences is increasingly interactive in character, with results in one area having important applications to research in other areas. For example, observance of chaotic behavior in dynamical (changing) systems has led to a virtual explosion of new mathematical research in analysis, applied mathematics and probability. It has raised deep, fundamental questions on the predictability of behavior and the effects of randomness. This research on "chaos" cuts across several traditional scientific boundaries, providing a fresh look at the seemingly irregular and complex phenomena observed in nature such as weather patterns, fluid dynamics, and population dynamics.

This modern trend toward increased interaction among scientific disciplines is further illustrated by ongoing programs on the chemistry of life processes, materials chemistry, and materials processing. The broad field of materials research is inherently multidisciplinary, deriving much of its vitality from contributions by a variety of scientific and engineering sub-disciplines.

Use of advanced computers as an adjunct to theoretical and experimental research is continuing to increase in importance. New insights and approaches are possible in the mathematical and physical sciences as a result of advances in computing, mathematical modeling, and algorithm development. MPS disciplines played a key role in many of these developments and will continue to play critical roles in the future.

Human resources remain a major concern of the MPS disciplines. In addition to the traditional support of graduate students and postdoctoral research associates, the disciplines emphasize research experience for undergraduate students, undergraduate curriculum development, and mentoring programs for women and minorities.

Other federal agencies also support academic research in the MPS disciplines, but in contrast to NSF, they focus on areas of mission relevance. MPS coordinates its funding with other agencies in a way that guards the overall health of U.S. science. Every effort is made to maintain the continuity and the broad support base of the research and yet avoid blunting planned mission agency emphases. NSF provides 44 percent of the total Federal support for academic-based research in the MPS disciplines.

Typically, coordination with other agencies is carried out through interagency coordinating committees. Each MPS Subactivity has participants on such committees, which consist of program officials from all relevant federal agencies. The larger programs, however, require more extensive and formal approaches to interagency coordination. Planning and coordination in elementary particle physics are carried out in the Department of Energy (DOE) High Energy Physics Advisory Panel (HEPAP), in which NSF actively participates. In nuclear science, this function is performed by the joint NSF-DOE Nuclear Science Advisory Committee (NSAC).

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Mathematical Sciences	$66.02	$76.05	$69.12	$-6.93	-9.1%
Astronomical Sciences	89.22	94.02	91.65	-2.37	-2.5
Physics	122.28	130.00	123.83	-6.17	-4.7
Chemistry	96.75	103.43	97.94	-5.49	-5.3
Materials Research	115.08	123.18	116.94	-6.24	-5.1
Science and Technology Centers	13.95	14.83	14.54	-0.29	-2.0
Major Research Equipment	0.50	12.00	42.99	30.99	258.3
Total, Activity	$503.80	$553.50	$557.01*	$3.51	0.6%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

The FY 1990 Current Plan is $557.01 million, an increase of $3.51 million, or 0.6 percent, above the FY 1990 Budget Request. This increase is the net of Congressionally mandated reductions to the total request, offset by supplemental FY 1990 funds provided by Congress for replacement of the Green Bank Telescope (GBT). Additional unobligated FY 1989 funds are also available for the GBT.

Within the FY 1990 allocation, priority is given to Astronomical Sciences and to undergraduate curriculum development in Mathematical Sciences, Physics, and Chemistry. Other priorities are maintained at a lower level of growth.

A new Subcctivity, Major Research Equipment, is established, including the Green B[illegible] Telescope from Astronomical Sciences and the National High Magnetic Field Labora[illegible] from Materials Research.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Mathematical Sciences	$69.12	$73.72	$4.60	6.7%
Astronomical Sciences	91.65	100.70	9.05	9.9
Physics	123.83	130.23	6.40	5.2
Chemistry	97.94	103.35	5.41	5.5
Materials Research	116.94	123.46	6.52	5.6
Science and Technology Centers	14.54	27.04	12.50	86.0
Major Research Equipment	42.99	63.00	20.01	46.5
Total, Activity	$557.01*	$621.50	$64.49	11.6%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank telescope, which is available in FY 1990.

The MPS Activity is increased by $64.49 million or 11.6 percent over the FY 1990 Current Plan, for a total of $621.5 million. The FY 1991 Request incorporates the Foundation's two central budget themes. The major emphasis in the FY 1991 Request is on instrumentation and human resources in order to help assure the future vitality of the MPS disciplines.

RESEARCH AND FACILITIES:

The FY 1991 request includes over $575 million for research and facilities, an increase of more than $52 million over FY 1990 levels.

- Two new major equipment projects are planned to provide unique research facilities: the Laser Interferometer Gravitational Wave Observatory and two 8-meter Optical/Infrared Telescopes. An increase of $20.01 million in the Major Research Equipment Subactivity is provided to initiate these projects, which involve substantial international cooperation.
- New technology in antenna design permits the performance of the 305-meter diameter reflector at the Arecibo Observatory to be improved significantly at modest cost. $5.0 million is requested to begin this project. The estimated cost over two years is $22.0 million, of which NASA will contribute 50 percent.
- Support for other equipment and instrumentation increases by about $10.0 million to a total in FY 1991 of over $94.0 million. In all, support for instrumentation and major equipment represents over 18 percent of the FY 1991 request.
- Support continues for the six Science and Technology Centers established in FY 1989, and an additional $12.5 million is included for new Science and Technology Centers to be

awarded as a result of the second competition held in FY 1990. The Howard University Minority Research Center of Excellence in materials research will be transferred to MPS.

- Support for graduate research assistants will increase by over $4.0 million to bring the MPS total to more than $58 million, for almost 5700 students.

Within the ongoing program a partial upgrade of the ultra-high energy cosmic ray detector (Fly's Eye) will begin. Focus on superconductivity research is maintained at the FY 1990 level of $24.1 million. Construction of the Very Long Baseline Array radio telescope continues, with completion planned for FY 1993.

EDUCATION AND HUMAN RESOURCES:

The FY 1991 request includes nearly $46 million for support of education and human resources, an increase of $12 million over the FY 1990 levels.

- Support for new investigators will be augmented by $4.8 million to fund 60 new research awards in emerging areas. This emphasis is in addition to new awards for Presidential Young Investigators.
- Strong undergraduate efforts will continue, including expanded course and curriculum development at the introductory level and Research Experiences for Undergraduates with an enhanced emphasis on mentorship. In all, support for undergraduate activities will increase more than $5.5 million, to over $18 million.
- Funds are also provided for new Foundation-wide activities to increase the participation of women and minorities in science and engineering.

CHANGES IN BUDGET STRUCTURE

The Major Research Equipment Subactivity was established in FY 1990 for new large scale construction projects.

MATHEMATICAL SCIENCES...$73,720,000

SUMMARY OF REQUEST

The FY 1991 Request for the Mathematical Sciences Subactivity is $73.72 million, an increase of $4.6 million, or 6.7 percent, over the FY 1990 Current Plan of $69.12 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Classical Analysis	$5.81	$6.47	$5.97	$6.22
Modern Analysis	5.78	6.46	5.96	6.21
Geometric Analysis	5.89	7.16	6.31	6.68
Topology and Foundations	7.04	7.87	7.24	7.55
Algebra and Number Theory	9.85	11.15	10.12	10.56
Applied Mathematics	8.13	9.21	8.30	8.70
Statistics and Probability	7.26	8.21	7.44	7.81
Computational Mathematics	4.74	5.85	4.91	5.22
Special Projects	11.52	13.67	12.87	14.77
Total, Subactivity	$66.02	$76.05	$69.12	$73.72

SCIENTIFIC OVERVIEW

The Mathematical Sciences Subactivity fosters the creation and development of mathematical ideas, methods, and techniques and promotes their use in improving our understanding of physical, biological, engineering, and social phenomena. Support for significant research and related infrastructure activities ensures the continuing vitality and long-range health of the discipline. All subdisciplines of the mathematical sciences, from those with the sharpest intrinsic focus to those that reach out to other areas of knowledge, are supported to encourage interaction and provide a healthy balance among them.

The core of the Foundation's program in the mathematical sciences is the support of standard research projects. Collaborative research efforts, inclusion of graduate students and postdoctoral researchers, and development and use of computational techniques are encouraged where appropriate.

Much of the current excitement in mathematics stems from the interactions between various subdisciplines and between mathematics and other areas of science and engineering.

- The Geometry Supercomputer Project based at the University of Minnesota involves researchers from across the country and Europe. Its Minimal Surface Team has developed a "Surface Evolver" program that models geometrically the evolution of surfaces driven by various forces such as surface tension, crystalline surface energy, gravity and pressure. The program will be an aid in developing and testing conjectures about surfaces. It is available to the public and will run on several different machines.

- How closely may equal-sized spheres be packed in space? This problem, and its analogues in more than three dimensions, is very important in communications theory where the packing solutions are used to determine efficient error-correcting codes. Recently Dr. Noam Elkies of Harvard University used seemingly unrelated concepts from number theory to find sphere packings, in higher dimensions, that are denser than any previously known.

The above examples reflect the impact of mathematics research on fields as diverse as materials science and information technology. They are typical of recent developments throughout mathematics and exhibit two related phenomena:

- Many of the most fundamental advances are being made by people with deep understanding of a wide range of mathematical and scientific topics.
- Application and theoretical development are operating in mutually enriching ways, with the computer's extension of the reach and power of mathematics a driving factor.

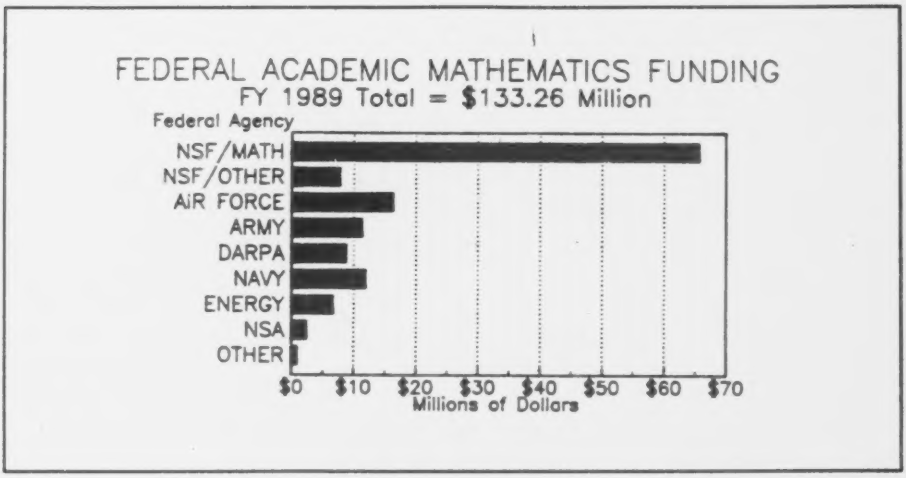
These observations have profound implications for the training of graduate students and for the continuing development of established researchers.

The Mathematical Sciences Subactivity also supports, through its Office of Special Projects, various efforts that cut across the mathematical sciences, including: research institutes and centers; postdoctoral research fellowships; research conferences, workshops and special years; shared scientific computing research equipment; and undergraduate programs managed in collaboration with the Science and Engineering Education Activity.

During the last few years, support for the mathematical sciences has emphasized improving the pool of talent entering the field. Significant gains have been made through added support for graduate students, postdoctoral researchers and undergraduate faculty and students. Support for undergraduate curriculum development in calculus was initiated in FY 1988 in cooperation with Science and Engineering Education.

The chart below illustrates the crucial role played by NSF in the federal support of academic research in the mathematical sciences. In all areas of the mathematical sciences, Foundation-supported research involves a broader range of basic research topics than the more project-oriented research sponsored by the mission agencies.

NSF coordinates its support of research in the mathematical sciences with its counterpart federal agencies through the Interagency Committee for Extramural Mathematics Programs (ICEMAP). This group meets regularly to share information on policies of support and to discuss areas of emphasis and of unusual scientific opportunity.



CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Classical Analysis	$5.81	$6.47	$5.97	$-0.50	- 7.7%
Modern Analysis	5.78	6.46	5.96	-0.50	- 7.7
Geometric Analysis	5.89	7.16	6.31	-0.85	-11.9
Topology and Foundations	7.04	7.87	7.24	-0.63	- 8.0
Algebra and Number Theory	9.85	11.15	10.12	-1.03	- 9.2
Applied Mathematics	8.13	9.21	8.30	-0.91	- 9.9
Statistics and Probability	7.26	8.21	7.44	-0.77	- 9.4
Computational Mathematics	4.74	5.85	4.91	-0.94	-16.1
Special Projects	11.52	13.67	12.87	-0.80	- 5.9
Total, Subactivity	$66.02	$76.05	$69.12	$-6.93	-9.1%

The FY 1990 Current Plan is $69.12 million, a decrease of $6.93 million (9.1 percent) from the FY 1990 Budget Request due to Congressionally mandated reductions. This represents an increase of $3.10 million (4.7 percent) over the FY 1989 level.

Within the FY 1990 allocation, priority will be given to modern geometric mathematics and to undergraduate course and curriculum development, particularly in calculus. Emphasis is also placed on interactions with other disciplines, computational mathematics, appropriate support for small research groups, and human resources issues of importance to the field.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Classical Analysis	$5.97	$6.22	$0.25	4.2%
Modern Analysis	5.96	6.21	0.25	4.2
Geometric Analysis	6.31	6.68	0.37	5.9
Topology and Foundations	7.24	7.55	0.31	4.3
Algebra and Number Theory	10.12	10.56	0.44	4.3
Applied Mathematics	8.30	8.70	0.40	4.8
Statistics and Probability	7.44	7.81	0.37	5.0
Computational Mathematics	4.91	5.22	0.31	6.3
Special Projects	12.87	14.77	1.90	14.8
Total, Subactivity	$69.12	$73.72	$4.60	6.7%

The FY 1991 Budget Request of $73.72 million is $4.6 million (6.7 percent) above the FY 1990 Current Plan. The main elements of this increase are expanded participation of women and minorities, enhanced undergraduate programs, and strengthened support for standard research projects with emphasis on graduate students and equipment.

Within Special Projects, the increase is directed to the following priorities:

- Undergraduate course and curriculum development. Efforts will continue in calculus and expand the focus to other introductory courses such as precalculus, discrete mathematics, geometry, and statistics.
- Activities in conjunction with the Alliances for Minority Participation program. The focus will be on the critical transitions between high school and undergraduate education and between undergraduate and graduate education, with an emphasis on mentoring.
- NSF Faculty Awards for Women. New awards will recognize and enhance the research of the increasing numbers of mid-career women with outstanding research credentials in the mathematical sciences.

Across other programs:

- Improving the accessibility of Foundation programs to new investigators is the focus of a $1.0 million increase. Approximately twenty more new investigators will be supported than would otherwise be possible.
- Increased support for graduate students and equipment is the emphasis of an increase of $1.4 million.

- Special attention will be given to strengthening research support in areas of opportunity such as interactions with other disciplines, computational mathematics, and incorporating geometric ideas and methods throughout the mathematical sciences.

ASTRONOMICAL SCIENCES...$100,700,000

SUMMARY OF REQUEST

The FY 1991 Request for the Astronomical Sciences Subactivity is $100.7 million, an increase of $9.05 million, or 9.9 percent, over the FY 1990 Current Plan of $91.65 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Astronomy Project Support	$28.65	$31.23	$30.42	$31.91
National Astronomy and Ionosphere Center	6.19	6.35	6.27	11.27
National Optical Astronomy Observatories	24.32	25.23	24.62	25.77
National Radio Astronomy Observatory	30.06	31.21	30.34	31.75
Total, Subactivity	$89.22	$94.02	$91.65	$100.70

SCIENTIFIC OVERVIEW

Astronomy is the application of physics, chemistry, and mathematics to the entire universe beyond the earth. The objective in astronomical sciences is to increase our understanding of the physical nature of the universe, particularly the solar system, the sun and individual stars, star clusters, the Milky Way and other galaxies, and special objects such as molecular clouds and quasars. In the last few years, studies have increasingly focused on the characteristics of the large-scale structure of the universe itself.

The Subactivity supports ground-based research in all areas of astronomy. Support is provided for a balanced program, particularly with respect to observational and theoretical studies, and also to wavelength coverage. Studies in the different portions of the spectrum complement one another and are essential to understanding the many and varied objects and phenomena in the universe. Advances in detector technology, particularly in the infrared and at submillimeter wavelengths, have greatly broadened the spectrum available to ground-based observers. Increasingly powerful instruments enable researchers to probe further out into space and further back in time in a quest to learn the origin, evolution, and fate of the universe and the celestial objects in it.

NSF also supports ground-based astronomical research through the three National Astronomy Centers. The National Astronomy Centers provide radio, optical, and infrared telescopes to the scientific community on the basis of scientific merit. The National Astronomy Centers meet national scientific needs and provide telescopes, associated instrumentation, and support beyond the means of most individual institutions:

- The National Radio Astronomy Observatory (NRAO) is headquartered at Charlottesville, Virginia, and operates radio telescopes at three sites. NRAO is currently constructing the Very Long Baseline Array (VLBA) which will consist of 10 automated 25-meter antennas spaced around the U.S. Data recorded at all 10 antennas will be processed by a central computer to synthesize images of a resolution equivalent to what could be obtained with a radio telescope 8,000 kilometers in diameter.

  In November, 1988, the 300-foot radio telescope at Green Bank, West Virginia, collapsed. An investigation showed that the collapse was due to a structural design flaw which could not have been foreseen at the time of construction of the telescope (1962). The telescope will be replaced by a modern instrument, the Green Bank Telescope (GBT). Funding for this effort is described in the Major Research Equipment Subactivity.
- The main facility of the National Astronomy and Ionosphere Center (NAIC) is the 305-meter fixed, spherical radio telescope located at Arecibo, Puerto Rico.
- The National Optical Astronomy Observatories (NOAO) provide large optical and infrared telescopes and related instruments to the scientific community. NOAO includes Kitt Peak National Observatory (KPNO), Cerro Tololo Inter-American Observatory (CTIO), and the National Solar Observatory (NSO).

Some highlights of recent research covered by this Subactivity include:

- Radio astronomers at the NRAO and the Jet Propulsion Laboratory (JPL) used the Very Large Array (VLA) to map planetary satellites by radar reflection for the first time. Observations of Saturn's moon, Titan, have shown that the reflectivity of the surface is consistent with the presence of a deep methane ocean but that such an ocean could not be spread uniformly over Titan's surface. The success of this project opens unique opportunities for mapping objects in the solar system.
- Astronomers using the 4-meter telescope at CTIO recently reported the discovery of a population of faint blue galaxies that could be the first galaxies formed in the universe. The galaxies were detected by utilizing the latest Charge-Coupled Device (CCD) technology and by pushing observing and image-processing techniques to their limits.
- Arecibo and Cornell University astronomers, using the 305-meter telescope, have discovered a cloud of hydrogen gas ten times larger than our own galaxy. The cloud, which consists of a diffuse envelope surrounding two large clumps of gas that may be merging, has been interpreted as evidence that galaxy formation is still proceeding in the universe.

NSF is the lead federal agency for ground-based astronomy, providing about two-thirds of the federal support to this area of science. There is extensive coordination with NASA at the program level.

The Subactivity participates in Foundation-wide programs of undergraduate education and development of human resources.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Astronomy Project Support	$28.65	$31.23	$30.42	$-0.81	-2.6%
National Astronomy and Ionosphere Center	6.19	6.35	6.27	-0.08	-1.3
National Optical Astronomy Observatories	24.32	25.23	24.62	-0.61	-2.4
National Radio Astronomy Observatory	30.06	31.21	30.34	-0.87	-2.8
Total, Subactivity	$89.22	$94.02	$91.65	$-2.37	-2.5%

The FY 1990 Current Plan is $91.65 million, a decrease of $2.37 million (2.5 percent) from the FY 1990 Request of $94.02 million, due to Congressionally mandated reductions. This represents an increase of $2.43 million (2.7 percent) over the FY 1989 level. The Astronomical Sciences Subactivity was given priority in the Foundation's FY 1990 Current Plan, in order to protect research and field operations.

Funds for construction of the VLBA are reduced from planned levels, although installation of telescopes remains on schedule for completion by 1993. Project support and operations of National Centers are constrained relative to planned levels.

FY 1991 BUDGET REQUEST

Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Astronomy Project Support	$30.42	$31.91	$1.49	4.9%
National Astronomy and Ionosphere Center	6.27	11.27	5.00	79.7
National Optical Astronomy Observatories	24.62	25.77	1.15	4.7
National Radio Astronomy Observatory	30.34	31.75	1.41	4.6
Total, Subactivity	$91.65	$100.70	$9.05	9.9%

The budget request of $100.7 million for Astronomical Sciences, an increase of $9.05 million, or 9.9 percent, over the FY 1990 Current Plan, will emphasize:

- Preparation for installation of a Gregorian subreflector for the NAIC 305-meter telescope ($5.0 million).
- Continuation of construction of the VLBA, at the FY 1990 level, and partial operations of completed VLBA antennas ($700,000 increase).

Operations of existing national facilities will be constrained.

ASTRONOMY PROJECT SUPPORT

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Solar System Astronomy	$1.05	$1.08
Stars and Stellar Evolution	6.78	7.04
Galactic Astronomy	6.60	6.86
Extragalactic Astronomy	9.83	10.46
Astronomical Instrumentation and Development	6.06	6.37
Electromagnetic Spectrum Management	0.10	0.10
Total	$30.42	$31.91

Project support covers all areas of ground-based astronomy, including research on the sun, the solar system, the structure and evolution of the stars, stellar distances and motions, the composition and distribution of interstellar gas and dust, the properties and motions of other galaxies, and cosmology.

Astronomical Sciences Project Support will be allocated $31.91 million, an increase of $1.49 million, or 4.9 percent, over FY 1990.

There will be particular emphasis in FY 1991 on the following areas of research:

- Continued emphasis on research related to cosmology and the structure of the universe.
- Continued development and acquisition of array detectors, particularly in the infrared region of the spectrum.
- Development of adaptive optics systems for moderate aperture (3- to 4-meter) telescopes .
- Development of large, lightweight borosilicate glass mirror blanks.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Scientific Research Support	$6.63	$6.65
Upgrade	1.00	8.10
Less NASA Support	1.36	3.48
Total	$6.27	$11.27

The National Astronomy and Ionosphere Center (NAIC) supports research in radio astronomy, radar astronomy, and the atmospheric sciences. The major research instrument is the 305-meter telescope (near Arecibo, Puerto Rico) which is the world's most sensitive and powerful radio/radar telescope. Additional facilities include a smaller interferometer antenna, an ionospheric heating facility, and an airglow facility. Cornell University operates NAIC. Atmospheric research is supported by the Atmospheric Sciences Subactivity.

In FY 1991, NAIC will prepare for installation of a Gregorian subreflector, a major upgrading of the 305-meter telescope to significantly increase its sensitivity and scientific capabilities. The NAIC upgrade consists of a ground screen, to begin in FY 1990; the Gregorian subreflector; and an improvement to the radar capability. Five million dollars is to be provided by NSF for this project in FY 1991. The estimated cost of the complete upgrade is $22.0 million. It will be cost-shared between NSF and NASA.

NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Scientific Research Support	$24.84	$26.00
Management Fee	0.41	0.42
Less DOD Support	0.63	0.65
Total	$24.62	$25.77

The National Optical Astronomy Observatories (NOAO) operates observing facilities at Kitt Peak National Observatory (KPNO), Cerro Tololo Inter-American Observatory (CTIO), and the National Solar Observatory (NSO).

KPNO is the largest center for ground-based astronomy available to U.S. researchers. Its optical telescopes are located on Kitt Peak (90 kilometers southwest of Tucson, Arizona) and include the 4-meter Mayall Telescope, the Nation's second largest optical telescope.

CTIO is the only southern hemisphere observatory generally available to U.S. researchers. Optical and infrared telescopes are located on Cerro Tololo, 65 kilometers inland from La Serena, Chile. The 4-meter telescope is the largest optical telescope in the southern hemisphere.

NSO provides unique instruments for high-resolution studies of the sun. The Vacuum Tower Telescope at Sacramento Peak, New Mexico, yields observations of the sun with higher angular resolution than any other ground-based telescope in the world. The McMath Solar Telescope (on Kitt Peak) is used for high angular and spectral resolution studies of the solar surface.

NSF funding of Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, and National Solar Observatory is:

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Kitt Peak National Observatory	$7.80	$8.10
Cerro Tololo Inter-American Observatory	5.10	5.30
National Solar Observatory	4.90	5.00

In FY 1991, NOAO will provide operations and maintenance of optical and infrared observational facilities for the scientific community at constrained levels. The development of instrumentation for the experiment to measure solar oscillations will proceed.

The detailed design phase for two 8-meter optical/infrared telescopes, one to be located in the Northern and one in the Southern Hemisphere, will be initiated with funds requested under the Major Research Equipment Subactivity.

NATIONAL RADIO ASTRONOMY OBSERVATORY

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Scientific Research Support	$18.85	$20.23
VLBA Construction	11.00	11.00
Management Fee	0.49	0.52
Total	$30.34	$31.75

The National Radio Astronomy Observatory (NRAO) is one of the world's principal centers for radio astronomy. A 140-foot single-dish telescope which can make observations in the range from centimeter to meter wavelengths is located at Green Bank, West Virginia. The Very Large Array (VLA) near Socorro, New Mexico, provides a unique combination of high sensitivity and resolution for radio astronomy observations. The 12-meter telescope on Kitt Peak is used for observations at wavelengths as short as 1 millimeter.

In 1985, NRAO began construction of the Very Long Baseline Array (VLBA). Headquarters are in Socorro, New Mexico. The VLBA will surpass all existing or planned telescopes in resolution, sensitivity, dynamic range, mapping capability, and frequency coverage, and it will be complementary to the VLA.

The FY 1991 estimate provides for the operation and maintenance of existing telescopes, associated instrumentation, and computational support at constrained levels, as well as operation of some antennas of the VLBA. The FY 1991 request for construction of the VLBA will provide funding for the installation of the remaining two antennas, receivers, and other electronic components of the system. Completion of the VLBA project is contemplated by 1993, and the total project costs are estimated to be about $82 million.

It is expected that the design of the new Green Bank Telescope, a 100-meter-class fully-steerable antenna, will be completed in 1990 and that construction will then proceed with funds available as shown under the Major Research Equipment Subactivity. Completion is anticipated in 1995.

PHYSICS..$130,230,000

SUMMARY OF REQUEST

The FY 1991 Request for the Physics Subactivity is $130.23 million, an increase of $6.40 million, or 5.2 percent, over the FY 1990 Current Plan of $123.83 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Elementary Particle Physics	$40.11	$43.43	$39.83	$41.33
Nuclear Sciences	41.90	44.71	42.00	43.50
Atomic, Molecular, Optical Physics	13.87	14.42	14.30	15.40
Theoretical Physics	16.61	17.09	17.40	18.70
Gravitational Physics	9.79	10.35	10.30	11.30
Total, Subactivity	$122.28	$130.00	$123.83	$130.23

SCIENTIFIC OVERVIEW

The Physics Subactivity supports the development of new knowledge about the existence, structure, and interactions of the various forms of matter and energy, and about the basic forces that govern these interactions.

The research program supports a range of activities needed to advance knowledge in the areas of elementary particle physics; nuclear physics; atomic, molecular, and optical physics; and gravitational physics. Both experimental and theoretical studies are required to advance our knowledge in each.

Balance is sought among the types of research activities supported. Besides research by individual and small groups, the research programs support experiments by large user groups at national and international facilities. Funding is also provided for large and small university-based accelerator centers whose facilities serve a national community of users, not only in physics, but also in materials research, biology, geology, oceanography and medical technology.

In theoretical physics, in addition to support for individual investigators, NSF provides funding for the Institute for Theoretical Physics (ITP) at Santa Barbara and the Institute for Theoretical Atomic and Molecular Physics at Harvard University (as part of the Harvard-Smithsonian Center for Astrophysics.) Major programs bring together at the ITP about two dozen scientists at a time for several months, facilitating communication and in some cases significantly increasing the pace of research on a particular topic. Although smaller in size and narrower in scope than the ITP, the Harvard-Smithsonian Institute is expected to have a major impact in attracting talented graduate students and supporting a visiting professorship program.

NSF support of elementary particle and nuclear physics merits special note. Although the Department of Energy (DOE) appears to have a dominant role, the crucial role of NSF is evident in the university component. In overall federal support, NSF provides about 8 percent of the funding for elementary particle physics research and about 20 percent for nuclear physics research. However, in support for academic research, NSF provides about one-third and one-half of the funding for these fields. This role of the NSF in support of university-based activities is important to the future science capability of the country, especially with regard to the entry of students into forefront research.

Through the Physics Subactivity, NSF supports the:

- Cornell Electron Storage Ring (CESR), one of the four national high energy accelerators; and
- Indiana University Cyclotron Facility (IUCF) and the Michigan State University National Superconducting Cyclotron Laboratory (NSCL), two of the seven major national nuclear accelerators.

Each of these facilities is unique in its capabilities and provides services unavailable at other laboratories in the United States. The significant role of NSF in supporting accelerator development activities is evident in recent success at these centers.

The first successful demonstration of the new device known as the "Siberian Snake" took place last year at the IUCF Cooler Ring. The Snake is actually a series of magnetic elements that can be inserted into circular accelerators, which then permit polarized beams to be maintained throughout the acceleration process. The Siberian Snake, in eliminating disturbing resonances, could be an important addition to very high-energy accelerators such as the planned Superconducting Super Collider (SSC). The Indiana University cooler ring is a medium-energy accelerator with only two depolarizing resonances to contend with, but the SSC will have about 36,000 such resonances. The Snake could eliminate the effects of these resonances automatically.

Other areas of NSF physics support include atomic, molecular, optical and general physics. Though significant support in certain of these areas is also provided by the Departments of Defense and Energy, the National Institute of Standards and Technology, and the National Aeronautics and Space Administration, they focus their research support in areas essential to agency mission. The NSF-funded activities preserve the essential balance in the field, since the NSF supports work of intrinsic scientific interest allowing long-range and speculative ideas to be investigated. In addition, NSF is almost totally responsible for the development and present health of ground-based gravitational physics.

Human resources are vital to the success of NSF programs in Physics. Physics has supported annually approximately 400 postdoctoral, 900 graduate and 400 undergraduate students. In addition to support under the regular grant program, approximately 150 undergraduates were supported last year by the Research Experiences for Undergraduates (REU) program. In 1989 there were thirteen REU group activities in Physics, such as the Florida State University program that brought together undergraduate students from ten different southeastern institutions for the summer to study and work with faculty in a variety of research areas.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Elementary Particle Physics	$40.11	$43.43	$39.83	$-3.60	-8.3%
Nuclear Sciences	41.90	44.71	42.00	-2.71	-6.1
Atomic, Molecular, Optical Physics	13.87	14.42	14.30	-0.12	-0.8
Theoretical Physics	16.61	17.09	17.40	0.31	1.8
Gravitational Physics	9.79	10.35	10.30	-0.05	-0.5
Total, Subactivity	$122.28	$130.00	$123.83	$-6.17	-4.7%

The FY 1990 Current Plan is $123.83 million, a decrease of $6.17 million (4.7 percent) from the FY 1990 Budget Request, due to Congressionally mandated reductions. This represents an increase of $1.55 million (1.3 percent) over the FY 1989 level.

Within the FY 1990 allocation, priority is given to theoretical physics; atomic, molecular, and optical physics; and to continued development for the laser interferometer gravitational wave detector. This has resulted in more severe reductions in elementary particle physics and nuclear sciences. These latter reductions will require that operations at major facilities remain essentially at their FY 1989 levels and that increases for particle detector research in elementary particle physics are not possible this year.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Elementary Particle Physics	$39.83	$41.33	$1.50	3.8%
Nuclear Sciences	42.00	43.50	1.50	3.6
Atomic, Molecular, Optical Physics	14.30	15.40	1.10	7.7
Theoretical Physics	17.40	18.70	1.30	7.5
Gravitational Physics	10.30	11.30	1.00	9.7
Total, Subactivity	$123.83	$130.23	$6.40	5.2%

The FY 1991 Budget Request of $130.23 million is $6.40 million (5.2 percent) above the FY 1990 Current Plan. The main elements of the requested increase are strengthening disciplinary base programs and enhancing undergraduate activities.

- Support for individual and group research activities receives an increase of $3.8 million above the FY 1990 base program of approximately $78 million. All program elements share in this increase.
- Elementary Particle Physics and Nuclear Sciences emphasize increased support for instrumentation research and development. Atomic, Molecular, and Optical Physics stresses support for new investigators, postdoctoral associates and graduate students. Continuing an emphasis begun in FY 1989, support for theoretical studies is significantly increased in both Theoretical Physics and Gravitational Physics.
- Special research initiative areas from previous years such as cosmology, complex systems and chaos, and cosmic ray detector development remain priority areas for support. Of particular note is the ongoing support for the development of an ultra-high energy cosmic ray detector, the Fly's Eye.
- Support for major facilities--the Cornell Electron Storage Ring (CESR), the Indiana University Cyclotron Facility (IUCF), and the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University--is increased by $500,000 to approximately $40.7 million.
- An increase of $1.6 million will support additional activities in undergraduate education and activities for addressing the participation of women and minorities in physics. In FY 1991 special emphasis will be given to continuing initiatives in undergraduate curriculum development begun in FY 1990. In addition, other undergraduate activities will be maintained at or above their FY 1990 levels.

CHANGES IN BUDGET STRUCTURE

The Intermediate Energy Nuclear Physics and Nuclear Physics program elements have been combined into one program element: Nuclear Sciences. This has been done to eliminate artificial boundaries between these two related areas. It is also consistent with similar groupings within the American Physical Society and with the DOE/NSF Nuclear Sciences Advisory Committee.

CHEMISTRY..$103,350,000

SUMMARY OF REQUEST

The FY 1991 Request for the Chemistry Subactivity is $103.35 million, an increase of $5.41 million, or 5.5 percent, over the FY 1990 Current Plan of $97.94 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Chemical Instrumentation	$8.25	$8.90	$8.10	$8.80
Organic and Macromolecular Chemistry	23.88	24.97	24.52	25.29
Physical Chemistry	28.46	29.84	29.06	30.48
Inorganic, Bioinorganic and Organometallic Chemistry	15.96	16.63	16.25	17.17
Analytical and Surface Chemistry	12.72	13.54	12.95	13.66
Special Projects	7.48	9.55	7.06	7.95
Total, Subactivity	$96.75	$103.43	$97.94	$103.35

SCIENTIFIC OVERVIEW

Chemistry is the science of molecules, the units of matter which constitute all materials and substances in the universe. Chemistry is also a science of people, because the groundbreaking advances in chemistry are repeatedly made by individuals and small groups of scientists in laboratories around the Nation. Chemistry has become a high-technology science with critical impact on our Nation's economy. Chemistry is one of the principal U.S. industries contributing a large positive balance of foreign trade.

Advances in chemistry propel developments in the energy, petrochemical, pharmaceutical, and agrichemical industries. Chemistry is equally essential to solving the most vexing environmental problems, including ozone depletion, acid rain and toxic waste. Perhaps most importantly, chemistry is the doorway to discovery and innovation undergirding future industries based on biotechnology and advanced materials.

Chemists, often in collaboration with materials scientists and engineers, have made remarkable recent progress in constructing materials by design. Important goals in this arena include new and more efficient synthetic routes to novel ceramics and electronics materials. High-risk, high-payoff efforts point at the ultimate in miniaturization of electronics -- the single molecule which functions as an electronic component. At the Massachusetts Institute of Technology, Mark Wrighton has synthesized individual molecules that function as transistors. Robert Grubbs at the

California Institute of Technology has developed revolutionary catalysts for making new plastics that are electrical conductors.

Biology too is now brought into the service of chemistry: natural, altered, and even man-made enzymes and enzyme mimics are being used to carry out chemical synthesis with newfound efficiency and specificity. E. J. Corey at Harvard University has discovered that small molecules with enzyme-like reactivity (dubbed "chemzymes") lead to highly efficient production of complex chemical products. Scripps Institute's Chi-Huey Wong (a Presidential Young Investigator) has pioneered efforts to use natural enzymes for high-yield synthesis of other chemical products.

Research support for chemistry is an interagency and intersectoral effort. Government support, provided principally by NSF, HHS, DOE, and DOD, is supplemented by nearly $60 million per year from chemical and related industries. NSF funds about one-fifth of total federal R&D in chemistry, and 40 percent of the federal support for chemistry at colleges and universities. The NSF role is unique since it focuses on fundamental research driven by scientific opportunity rather than by developmental mission.

- Disciplinary research in chemistry is problem focused. Projects are directed toward discovery and characterization of new substances, selective separation and purification, synthesis of new materials with designed properties, elucidation of how chemical processes occur, and formulation of general laws governing chemical structure and reactivity.
- University-based research facilities are augmented through a shared instrumentation program which provides, on a cost-sharing basis, state-of-the-art major equipment items essential to modern research. Research teams sharing instrumental resources and ideas develop new analytical techniques and improved instrumentation as part of problem-solving research.
- Centers and organized groups are an increasingly important research mode in the interdisciplinary chemistry of the 90's. Chemistry shares support of group-collaborative research in Chemistry of Life Processes, and Materials Chemistry and Chemical Processing initiatives with NSF units responsible for biology, materials science and engineering.
- Human resource development is an urgent and continuing need in Chemistry. Improved participation by women and minority chemists is a prime decision factor in all Chemistry research support. Chemistry supports 45 national sites for summer Research Experiences for Undergraduates, providing hands-on research education for 500 future scientists and engineers. Chemistry has also instituted a highly competitive Postdoctoral Fellowship Program to provide research training on emerging chemical frontiers. Postdoctoral Fellowships also address growing faculty shortages by providing a "starter grant supplement" to encourage pursuit of academic careers.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY1990 Current Plan	Change Amount	Change Percent
Chemical Instrumentation	$8.25	$8.90	$8.10	$-0.80	-9.0%
Organic and Macromolecular Chemistry	23.88	24.97	24.52	-0.45	-1.8
Physical Chemistry	28.46	29.84	29.06	-0.78	-2.6
Inorganic, Bioinorganic and Organometallic Chemistry	15.96	16.63	16.25	-0.38	-2.3
Analytical and Surface Chemistry	12.72	13.54	12.95	-0.59	-4.4
Special Projects	7.48	9.55	7.06	-2.49	-26.1
Total, Subactivity	$96.75	$103.43	$97.94	$-5.49	-5.3%

The FY 1990 Current Plan is $97.94 million, a decrease of $5.49 million (5.3 percent) from the FY 1990 Budget Request, due to Congressionally mandated reductions. This represents an increase of $1.19 million (1.2 percent) over the FY 1989 level.

Disciplinary research project support is increased slightly over FY 1989 levels. Within this envelope, priority will be given to maintaining key research programs by scaling back or eliminating support for mature projects.

Chemical Instrumentation is reduced below 1989 levels, primarily due to deferral of some Instrumentation and Laboratory Improvement grants to FY 1991. Other shared research instrumentation purchases will be held to FY 1989 levels. Dedicated equipment funding for individual projects will increase modestly.

The change in Special Projects includes a planned funding reduction ($1 million) for regional instrumentation facilities which are being phased down. It also includes modest growth for Research Experiences for Undergraduates and Postdoctoral Fellowships in Chemistry. New funds are provided for needed modernization and improvement in the undergraduate chemistry curriculum, to commit research scientists to greater teaching efforts.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Chemical Instrumentation	$8.10	$8.80	$0.70	8.6%
Organic and Macromolecular Chemistry	24.52	25.29	0.77	3.1
Physical Chemistry	29.06	30.48	1.42	4.9
Inorganic, Bioinorganic and Organometallic Chemistry	16.25	17.17	0.92	5.7
Analytical and Surface Chemistry	12.95	13.66	0.71	5.5
Special Projects	7.06	7.95	0.89	12.6
Total, Subactivity	$97.94	$103.35	$5.41	5.5%

The FY 1991 Budget Request of $103.35 million is 5.5 percent above the FY 1990 Current Plan. The requested increment of $5.41 million is divided between enhancements in disciplinary research, and education and human resources.

- Support will be increased for selected research projects with unusual potential at the frontiers of chemical knowledge. An increment of $2.11 million is targeted to increased support for graduate student research assistants, and a parallel increment of $700,000 is intended for new, special-purpose instrumentation. When combined with funds redirected from projects of lower urgency, this $2.81 million increase will provide modest productivity growth in the most excellent research groups across all Chemistry programs.
- An increase of $1.70 million is requested for 20 additional new investigators in the Chemistry Subactivity. Young scientists with fresh ideas are the discipline's lifeblood. Funding for their research programs is essential to maintain academic careers as a competitive career track and to avoid future shortages of college teachers. These new grants are in addition to new Presidential Young Investigator awards and new grants otherwise provided .
- An increment of $900,000 to the Special Projects Office is targeted to continued growth in the 50-site nation-wide program of Research Experiences for Undergraduates and in the course and curriculum improvement activity.
- Two interdisciplinary initiatives -- Materials Chemistry and Chemical Processing, and Chemistry of Life Processes -- will continue. Included are such critical research areas as superconductivity, advanced materials for information technologies, the chemistry of the senses, membrane chemistry, and man-made enzymes. An increase of $1.20 million to fund additional collaborative research at the interfaces of chemistry with materials research, chemical engineering, and biological sciences will be provided by redirecting funds from more mature research activities.

MATERIALS RESEARCH..*$123,460,000*

SUMMARY OF REQUEST

The FY 1991 request for the Materials Research Subactivity is $123.46 million, an increase of $6.52 million, or 5.6 percent, over the FY 1990 Current Plan of $116.94 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Materials Research Project Support	$64.83	$69.61	$66.06	$69.16
Materials Research Laboratories and Groups	34.22	36.20	34.55	36.90
National Facilities and Instrumentation	16.03	17.37	16.33	17.40
Total, Subactivity	$115.08	$123.18	$116.94	$123.46

SCIENTIFIC OVERVIEW

The Materials Research Subactivity supports research to advance the fundamental understanding of the physics and chemistry of materials, to promote the development of new materials with novel or superior properties, and to further the understanding of interrelationships among synthesis and processing, structure and composition, properties, and performance of materials at molecular, microscopic, and macroscopic levels.

Materials research yields major advances in science and engineering, such as universal principles of phase transformations and new classes of materials with special properties. The spectacular discovery of the high-temperature superconducting ceramic materials and the ability to fabricate nano-scale semiconductor structures are just two examples of the vitality of this field of research.

Theoretical research plays a significant role in the study of advanced materials. For example, a fundamentally new concept in the behavior of electrons confined to a two-dimensional plane has evolved from research at the Institute for Theoretical Physics at the University of California at Santa Barbara together with findings of other investigators in the condensed matter theory community. This may be the concept needed to model the behavior of the electrons in atomically thin films of semiconductors and in high-temperature superconductors.

Materials researchers are also pioneering in the development of techniques to study very rapid changes in the structure of biomolecular and other materials. A team from the Cornell High Energy Synchrotron Source, Argonne National Laboratory and Spectra Technology Inc., recently designed and built a magnetic device called an undulator which can be used to take x-ray flash pictures with an exposure time of one ten-billionth of a second.

Advanced computing plays an increasingly important role in the conduct of materials research. Scientists and engineers are now able to solve problems of a complexity considered prohibitive only a few years ago. The design of new materials from first principles has now become a reality.

Materials research also provides essential scientific and engineering knowledge necessary for new technological advances. Many technologies are limited by materials properties, and indeed, advances in key technologies are critically dependent on novel and advanced materials. Today, materials research plays a central and increasingly important role in worldwide economic competition.

Materials research is inherently multidisciplinary. It involves the cooperative interaction of scientists and engineers from many disciplines, including mathematics, condensed matter physics, chemistry, materials science, branches of engineering, and the biological sciences. The optimal balance between disciplinary and multidisciplinary activities is a goal of the Subactivity. Consequently, Materials Research support is provided through three different funding modes:

- Support for individual investigator research is provided through the Materials Research Project Support Program.
- Multi-investigator research is supported primarily by the Materials Research Laboratories and Groups Program through support for the interdisciplinary Materials Research Laboratories (MRL), and, on an intermediate scale, for Materials Research Groups (MRG).
- Support for national user facilities and major instrumentation is provided through the National Facilities and Instrumentation Program. The user facilities include centers for synchrotron radiation, small-angle neutron scattering, high magnetic fields, and high resolution electron microscopy.

In recognition of the increasing importance of materials chemistry, the Subactivity is engaged in a joint initiative in this area of research with the Chemistry Subactivity and the Engineering Activity.

The Subactivity is actively involved in developing and retaining human resources. In FY 1989, support was provided for about 1650 graduate students, 300 undergraduate students, and 450 postdoctoral researchers. Awards were also provided primarily to young scientists and engineers who had not yet received federal research support, through a special initiative in the area of superconductivity. In addition, participation in Foundation-wide special focus efforts for women, minorities, and the disabled are an important aspect of this involvement. For example in FY 1989, supplements were provided to three Materials Research Laboratories allowing the participation of 25 minority undergraduates in interdisciplinary research programs.

NSF provides about 50 percent of federal support for university-based research in the field of materials research. The remainder is largely funded by DOD and DOE. However, many materials research programs supported by other agencies are necessarily focused on areas important to their missions. The Materials Research Subactivity therefore endeavors to provide a broad base of fundamental research support. Coordination with other federal agencies is carried out through the Interagency Materials Group, a subcommittee of the Committee on Materials (COMAT), Office of Science and Technology Policy (OSTP).

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Materials Research Project Support	$64.83	$69.61	$66.06	$-3.55	-5.1%
Materials Research Laboratories and Groups	34.22	36.20	34.55	-1.65	-4.6
National Facilities and Instrumentation ..	16.03	17.37	16.33	-1.04	-6.0
Total, Subactivity	$115.08	$123.18	$116.94	$-6.24	-5.1%

The FY 1990 Current Plan is $116.94 million, a decrease of $6.24 million (5.1 percent) from the FY 1990 Budget Request, due to Congressionally mandated reductions. This represents an increase of $1.86 million (1.6 percent) over the FY 1989 level.

Within the FY 1990 allocation, priority is given to materials theory, through expanded scope and increased support. Support for other areas will also be increased, but at a lower rate than planned. The Current Plan reflects a restructuring of the Subactivity budget, as described below under Changes in Budget Structure.

Within the FY 1990 allocation for the Mathematical and Physical Sciences (MPS) Activity, funds are made available to start the construction of the new National High Magnetic Field Laboratory. This five-year construction effort is more fully described in the MPS Major Research Equipment Subactivity.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Materials Research Project Support	$66.06	$69.16	$3.10	4.7%
Materials Research Laboratories and Groups	34.55	36.90	2.35	6.8
National Facilities and Instrumentation	16.33	17.40	1.07	6.6
Total, Subactivity	$116.94	$123.46	$6.52	5.6%

The FY 1991 Budget Request of $123.46 million is $6.52 million (5.6 percent) above the FY 1990 Current Plan. The main elements of this increase are strengthening project support, establishing a new group, enhancing support for instrumentation, and developing human resources.

- Strengthening project support continues to be a high priority of the Materials Research Subactivity. An increase of $3.1 million is requested for this purpose. Support for fundamental research in biomolecular materials and in the synthesis and processing of advanced materials will be increased. Focus continues on high temperature superconductivity research with support remaining at the FY 1990 level of $17.3 million. Support for instrumentation essential for the conduct of project research will also be increased.
- Support for group activities is provided through the Materials Research Laboratories and Groups Program. The requested increase of $2.35 million will enable one additional group to be established (for a total of 18 groups) as part of a continuing effort to increase the number and expand the scope of MRGs. This increase will also permit strengthening of the MRLs.
- In addition, this increase includes $1.0 million for the continued development of the Minority Research Center of Excellence at Howard University. This center conducts research and trains students in the areas of electronic and opto-electronic materials. Responsibility for this center will be transferred to the Materials Research Subactivity from the Research Initiation and Improvement Subactivity.
- The requested increase for the National Facilities and Instrumentation Program is $1.07 million, which will be used to strengthen, upgrade, and complete construction of existing user facilities, and to support the acquisition of additional major instrumentation for shared use.

Within the requested increase for disciplinary and multidisciplinary activities, enhanced support is provided for undergraduate and graduate students, and to attract and retain more scientists and engineers in the field. Special emphasis will be placed on increasing the participation of women, underrepresented minorities, and the disabled. Undergraduate curriculum development is an important aspect of the Subactivity's involvement in the development of human resources.

CHANGES IN BUDGET STRUCTURE

Support for major instrumentation ($3.95 million in FY 1990) has been moved from the Materials Research Project Support program element and added to the National Facilities program element. The new National Facilities and Instrumentation program element better represents the way in which the Subactivity supports and encourages shared use of major national facilities and instrumentation.

Science and Technology Centers *$27,040,000*

Summary of Request

The FY 1991 Budget Request for the Science and Technology Centers Subactivity is $27.04 million, an increase of $12.5 million, or 86.0 percent, over the FY 1990 Current Plan of $14.54 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science and Technology Centers	$13.95	$14.83	$14.54	$27.04

Scientific Overview

The National Science Foundation established the Science and Technology Research Centers (STCs) Program in September 1987 to promote basic research that can most effectively be accomplished through centers - complex research problems that are large-scale, of long duration, and that may require special facilities or collaborative relationships across scientific and engineering disciplines.

The STCs are a response to the desirability of encouraging university-government-private sector collaborations, developing a research knowledge base in science and technology that will contribute to the economic and educational competitiveness of the U.S. In addition the STCs are providing students with experience in an interactive, multidisciplinary research setting as well as providing a strong grounding in disciplinary science.

Six of the eleven centers funded in February 1989 are in the MPS Activity. Four MPS centers focus on aspects of materials research, one on chemistry, and one on astrophysics. These investments have already achieved impressive results. For example:

- Researchers at the Center for Quantized Electronic Structures at the University of California, Santa Barbara, have succeeded in fabricating the world's first quantum wire superlattice. The novel properties of this superlattice promise revolutionary electronic devices in the next century.
- High temperature superconductivity is being investigated at the University of Illinois STC in conjunction with researchers at Northwestern, the University of Chicago, and Argonne National Laboratory. To insure that there is industrial awareness of these efforts, the Executive Advisory Board of this STC includes representatives of start-up companies as

well as major corporations such as General Electric, AT&T, Ford, General Motors, and Dupont.

- Researchers at the Center for Particle Astrophysics at the University of California at Berkeley, Lawrence Berkeley Laboratory, and other California universities will study the nature of the ninety percent of the universe that consists of dark matter. In order to proceed with the experimental studies, novel high sensitivity detectors will be developed, which may find broader use in medical and industrial applications.
- The University of Rochester has formed the Center for Photoinduced Charge Transfer in partnership with both the Eastman Kodak Company and Xerox Corporation. Collaborative investgation will be carried out concerning how light drives important chemical reactions, including naturally occurring processes such as photosynthesis. Both of these industrial partners will provide access to their laboratories in the search for answers to the questions which have significant impact on the industrial competitiveness of each in world markets.
- The Center for Advanced Cement Based Materials at Northwestern University also involves participation of the Universities of Illinois and Michigan, Purdue Univerity, and the National Institutes of Standards and Technology. The goal is to create an interdisciplinary materials science approach to the understanding of high-performance cement based materials. Considering the estimates for replacement of crumbling infrastructure in the U.S., there is an enormous future role of this Center in cost savings for the country.
- The Virginia Polytechnic Institute and State University has formed the Center for High-Performance Polymeric Adhesives and Composites. The major goal is to achieve a better understanding of the basic science and technology of polymer adhesives and composites. In the future the aerospace, automotive, and building industries, among others will heavily depend on these materials, giving the significant applied impetus to the research.

CHANGES BETWEEN FY199O REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Science and Technology Centers	$13.95	$14.83	$14.54	$-0.29	-2.0%

The reduction from the request represents the Subactivity's share of Gramm-Rudman-Hollings sequestration and the mandated across-the-board reduction for the war on drugs.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Science and Technology Centers	$14.54	$27.04	$12.50	86.0%

The FY 1991 Budget Request for STCs in the MPS Activity is $27.04 million. This provides for full funding of the 1989 class and funding for the second class of STCs in FY 1991.

The five-year cooperative agreements for the initial MPS STCs called for modest increases to bring the centers up to full operational levels. That objective could not be fully met in 1990 due to across-the-board reduction to the Subactivity; the existing centers will be restored to the planned level in FY 1991.

New STC proposals for 1991 awards are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for these awards have been distributed to the four research Activities based upon proposals in each set of disciplines. Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

MAJOR RESEARCH EQUIPMENT..$63,000,000

SUMMARY OF REQUEST

The FY 1991 Request for the Major Research Equipment Subactivity is $63.0 million, an increase of $20.01 million or 46.5 percent, over the FY 1990 Current Plan of $42.99 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Major Research Equipment	$0.50	$12.00	$42.99*	$63.00

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

SCIENTIFIC OVERVIEW

The National Science Foundation has long been a source of support for unique national research facilities. This investment has served dual purposes: it has made available resources necessary to build and support costly, large-scale instruments and equipment; and, it has ensured access to such tools by researchers.

Examples of large-scale research equipment supported by the NSF include telescopes, academic research vessels, accelerators, synchrotron radiation facilities, and, most recently, supercomputers and high-speed networks.

If the U.S. is to maintain leadership in science and technology and provide the research tools necessary for scientists and engineers to take advantage of opportunities, new equipment must be developed and built.

Four major research equipment projects are planned under this initiative: the Green Bank Telescope, a new National High Magnetic Field Laboratory, a Laser Interferometer Gravitational Wave Observatory, and two 8-meter Optical/Infrared Telescopes in collaboration with international partners. Each of these facilities is based upon new opportunities which hold the promise to advance science in significant ways.

GREEN BANK TELESCOPE

The new Green Bank Telescope (GBT) will be a 100-meter-class, high-quality, single-dish instrument capable of observing at wavelengths from a few meters to at least 7 millimeters, with a possibility of the short-wavelength range to extend to 3 millimeters. It will replace and surpass the 300-foot radio telescope at Green Bank, West Virginia, which collapsed in November 1988.

When completed, the GBT will be the largest steerable single dish radio telescope in the world. Its unblocked aperture will greatly improve the sensitivity, and its design will also allow much better image identification. The active control of the surface, together with superior panel quality, will allow much improved source imaging at high frequencies.

The telescope is expected to have significant impact on several areas of astronomical science. For example, in solar physics multifrequency imaging of active regions and of the undisturbed chromosphere/corona will improve understanding of solar activity. For pulsars, the high sensitivity and full sky coverage will drastically increase the data base for globular clusters and improve timing accuracy. In addition, the GBT will allow the determination of the molecular content of galaxies in their early stages. Other areas of impact include measurements of the total mass of the galactic disk, searches for rare objects, and very long base line interferometry (VLBI) including use in conjunction with space-based VLBI dishes.

NATIONAL HIGH MAGNETIC FIELD LABORATORY

Research using high magnetic fields has played a key role in the advancement of our knowledge of the physical, chemical, biological and engineering properties of materials. For example the current understanding of semiconductors and superconductors, and the impact of nuclear resonance spectroscopy in many disciplines, are testimony to the importance of high magnetic field research.

Even higher magnetic fields than currently available would provide opportunities for exciting new discoveries in physics, chemistry, biology and material sciences and engineering. Very high field magnets are necessary to perform the most crucial experiments for understanding high-temperature superconductivity. The possibility of developing very high field nuclear magnetic resonance spectrometers would permit the complete characterization of large biological molecules and their interactions.

The development of the new National High Magnetic Field Laboratory (NHMFL) will be guided in large part by a report prepared by a national panel of experts (Seitz-Richardson Panel Report, July 1988.) This facility will keep the U.S. at the forefront of high magnetic field research. The National Science Foundation has solicited proposals for the establishment of the laboratory and will make the initial award in FY 1990. Construction is expected to be completed over a five year period.

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Gravitational waves are perturbations of space-time predicted by theories of relativity. They should result from bulk motion of matter in distant regions of strong gravitational fields, such as in collapsing stellar cores and in collisions of black holes. A background of primordial gravitational waves may provide information about initial conditions in the universe (the Big Bang).

The objectives of the search for gravitational waves include: (1) tests of Einstein's General Theory of Relativity; and (2) the opening of a fundamentally new observational window on the universe.

Gravitational waves are expected to distort space as they pass and should be detected by measuring the extremely small motion between masses separated by carefully monitored distances. Early attempts to detect gravitational waves in the 1960s used massive bar detectors. These early attempts were unsuccessful because the sensitivities achieved were not high enough to measure the very weak signals. Designs based on the concept of a laser interferometer began developing in the 1970s.

Scientific teams have been working for the past decade and have successfully met milestones to demonstrate scientific feasibility for a laser interferometric system. Parallel foreign projects are proceeding rapidly, and the United States can have a large role in shaping a cooperative effort to open the field of gravity wave astronomy.

In the United States, a collaborative venture between California Institute of Technology and the Massachusetts Institute of Technology is designing a Laser Interferometer Gravitational Wave Observatory (LIGO). This project will consist of two detectors, widely separated within the continental United States, each having an L-shaped configuration with arms about 4 kilometers in length.

Two identical, but widely separated, detectors are needed for the physics experiment, to verify the existence of gravitational waves. To locate the source of a gravitational wave signal on the sky requires a minimum of four geographically separate but technically compatible detectors. Two European collaborations (United Kingdom/Germany and France/Italy) are planning detectors of compatible design and similar costs to the LIGO facility. They, along with the two U.S. detectors, would provide the geographic dispersion required for source detection.

8-METER OPTICAL/INFRARED TELESCOPES

Astronomers making use of the latest theoretical and observational results believe that they can trace the rough outline of the history of the universe from the first seconds after it began. Clues to a better, and perhaps even radically different, understanding of the origin and evolution of the structure in the universe emerge from disagreements between present observations and theory. Important questions need to be resolved about the age and rate of expansion of the universe, its overall topology, the epoch of galaxy formation, and the evolution of galaxies once they are formed, the formation of stars, and the possibility of planetary systems beyond our own.

Astronomers require observational tools that provide better sensitivity, spectral and spatial resolution. During the past 2 decades, advances in sensitivity in astronomy have depended in large measure on improvements in detectors. Major gains in the capabilities of detectors are no longer possible because existing devices already approach the theoretical limits of their performance. Additional gains must be achieved through increased aperture of telescopes.

It now appears possible to build a new generation of optical/infrared telescopes with significantly larger aperture (8-meter-diameter) than existing instruments. Technological advances in a number of key areas of telescope construction and design, especially the development of lightweight mirrors, will allow these instruments to take advantage of the best performance the atmosphere will allow.

The construction of two 8-meter telescopes, one in each hemisphere, is planned as an international collaboration with the United Kingdom and Canada as prospective partners. The U.S. will provide approximately 50 percent of the project costs.

Coverage of both hemispheres is essential because certain astrophysically important objects, such as the Magellanic Clouds, are observable only from the Southern Hemisphere. Also, several space observatories will be launched during the next decade and experience with previous orbiting telescopes has shown that most important discoveries from space require ground-based follow-up study necessitating full-sky coverage.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Major Research Equipment	$0.50	$12.00	$42.99*	$30.99	258.3%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

The FY 1990 Current Plan for Major Research Equipment is $42.99 million. This includes two projects: the Green Bank Telescope ($36.99 million) and the National High Magnetic Laboratory ($6 million).

The Congress provided $75 million for the Green Bank Telescope in two parts, $37.5 million in FY 1989 and $37.5 million in FY 1990:

- In FY 1989, $500,000 was obligated for design studies necessary prior to construction, with the remaining $37 million carried forward to FY 1990.
- The FY 1990 increment of $37.5 million was reduced to $36.99 million by Gramm-Rudman-Hollings sequestration.
- Thus, a total of $73.99 million is available for the GBT in FY 1990.

In the FY 1990 Current Plan, $6.0 million is included for the National High Magnetic Field Laboratory, originally requested at $12.0 million in the Materials Research Subactivity. This decrease of $6.0 million from the FY 1990 Budget Request is due to Congressionally mandated reductions. Within the allocation, priority will be given to initiating construction of long lead-time equipment (a state-of-the-art power supply and the very high field steady-state magnet). Other items will be deferred until FY 1991.

FY 1991 BUDGET REQUEST

Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Major Research Equipment	$42.99*	$63.00	$20.01	46.5%

*Does not include additional $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

The FY 1991 Budget Request of $63.0 million is $20.01 million or 46.5 percent above the FY 1990 Current Plan. The major elements of this increase provide for continuation of the National High Magnetic Field Laboratory, design and initial construction of the Laser Interferometer Gravitational Wave Observatory, and design for 8-Meter Optical/Infrared Telescopes. Specifically:

- **Green Bank Telescope:** In FY 1990, engineering design efforts will concentrate on definition for the final design. By FY 1991, the GBT project should be ready to initiate site development and construction of the telescope. Upon its completion in 1995, the GBT will add unique new capabilities to the facilities available to U.S. radio astronomers. It will be a crucial element in the net used for intercontinental VLBI observations, particularly when a satellite-borne VLBI antenna becomes available.
- **National High Magnetic Field Laboratory:** The FY 1991 request includes $12.0 million for construction and development of additional magnets, the acquisition of instrumentation, and the establishment of an in-house research program. The establishment of the laboratory is expected to be completed over a five-year period at a total estimated cost of $100 million. The cost of establishing and operating the laboratory is intended to be heavily cost-shared between NSF and other sources.
- **Laser Interferometer Gravitational Wave Observatory:** $47.0 million is provided to begin this 4-year construction project, which has a total estimated cost of $192 million. In the first year, focus will be on design work and procurement of components for the first of two sites. This will include development of a site plan and earthwork, design of corner, end, and midstation buildings, and engineering for vacuum systems, beam tube modules, vacuum chambers and monitoring and control systems. In addition, work will continue on interferometer design and testing.
- **8-Meter Optical/Infrared Telescopes:** The request for FY 1991 provides $4.0 million for engineering design studies of the telescopes and the purchase of glass for the first mirror. Construction of the first telescope would begin in 1992. The project would take 8 years to complete, with the first telescope operational in 6 years and the second 2 years later. The total cost for the two telescopes, instrumentation, and auxiliary facilities is estimated to be $176 million, of which the U.S. would provide approximately 50 percent.

Major Research Equipment

Millions of Dollars)

	FY 1990 Availability*	FY 1991 Estimate
Green Bank Telescope	$73.99	$0.00
National High Magnetic Field Laboratory	6.00	12.00
Laser Inteferometer Gravitational Wave Observatory	N/A	47.00
8-Meter Optical/Infrared Telescopes	N/A	4.00

*Includes $37.0 million unobligated balance from FY 1989 special appropriation for Green Bank Telescope, which is available in FY 1990.

CHANGES IN BUDGET STRUCTURE

The Major Research Equipment Subactivity was established with the FY 1990 Current Plan. It incorporates funds provided by the Congress in FY 1989 and FY 1990 for the Green Bank Telescope, as well as funds requested in the Materials Research Subactivity in FY 1990 for the National High Magnetic Field Laboratory. Additional new major equipment construction is included in FY 1991. At the time of completion of construction, operations and maintenance support will be assumed by the relevant Subactivity.

RESEARCH FACILITIES MODERNIZATION $20,000,000

Summary of Request

The FY 1991 Budget Request for the Research Facilities Modernization Activity is $20 million, an increase of $ 0.31 million, or 1.6 percent, over the FY 1990 Current Plan of $19.69 million.

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Research Facilities Modernization	$0.00	$0.00	$19.69	$20.00

NSF Role

The nation's economic well-being and competitiveness are based on broadening and strengthening the institutional research base for continued leadership in science and technology.

State-of-the-art facilities and equipment are important in helping determine what research will be done and how productive it will be. Research laboratories and facilities are an integral part of the nation's capability to obtain the highest quality research and ensure the availability of well-trained future scientists and engineers. NSF has a major role in supporting and encouraging others to support research facilities. The Research Facilities Modernization Activity involves:

- assessing research facility capacity and future needs;
- helping delineate roles of others and encouraging their investment in facilities; and
- developing initiatives and providing support for modernizing research facilities.

As summarized in NSF's June 1989 report to Congress, *Modernizing Academic Research Facilities: A Comprehensive Plan* (NSF 89-61), recent surveys and assessments indicate that academic research facilities have deteriorated and that there is a need to repair, renovate, and modernize them as well as to provide new construction. Research facilities are often inadequate or obsolete and frequently do not meet current health, safety, and other standards.

The Research Facilities Modernization Activity responds directly to the legislative mandate of the Academic Research Facilities Modernization Act of 1988, which authorized NSF to establish and carry out a program for developing initiatives and providing support for modernizing research facilities. The program provides competitive grants for the repair, renovation, or, in exceptional cases, replacement of laboratories and other research and research training facilities.

The program's primary goals are:

- to promote the modernization of science and engineering research laboratories and related facilities at institutions of higher education (both graduate and undergraduate institutions), independent nonprofit research institutions, research museums, and consortia thereof;
- to assist those academic institutions that historically have received relatively little federal funds to improve their science and engineering infrastructures; and
- to broaden and strengthen the nation's science and engineering base.

Eligible facilities are limited to general research and research training facilities used for any field of science, mathematics and engineering ordinarily supported by NSF. Proposals are limited to one per eligible organization per proposal cycle. Organizations will be expected to cost share (from non-federal sources) a minimum of 50 percent of the total project costs.

The proposal submission and competitive review process will be conducted in two phases -- an abbreviated Phase I proposal followed by limited invitations to submit a more detailed Phase II proposal. Awards will be made to graduate, undergraduate, and other types of institutions, covering a broad range of NSF-supported scientific and engineering disciplines. Awards are expected to have an average duration of three years.

CHANGES BETWEEN FY1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Research Facilities Modernization	$0.00	$0.00	$19.69	$19.69	N/A

The FY 1990 Current Plan is $19.69 million, which reflects Congressionally mandated budget reductions. The initial program solicitation has been issued. Awards are expected to be made late in the fiscal year, as described in the next section.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Research Facilities Modernization	$19.69	$20.00	$0.31	1.6%

The Research Facilities Modernization Activity is increased by $0.31 million or 1.6 percent over the current plan to a total of $20 million consistent with the conference report accompanying the FY 1990 appropriation. The FY 1991 request strengthens the Foundation's central budget themes by providing needed capital infrastructure support for research and research training activities.

As noted above, the initial program solicitation has been issued. Due to the high costs of facilities projects and anticipated proposal volume, proposals submitted in this initial proposal cycle will be competing for FY 1990 and FY 1991 funds. It is anticipated that the first awards will be made late in FY 1990, with the balance being made early in FY 1991. This approach will increase the number of awards possible for the same level of proposal preparation and review effort.

In an effort to leverage the federal funds, the program requires awardees to provide substantial cost sharing from non-federal sources. This requirement encourages financial involvement by other key groups with an interest and role in supporting academic research facilities, such as state and local governments, research institutions themselves, industry, private foundations, and others.

Evaluation criteria include research merit, facility need, project impacts, and plans and funding. By law, the Foundation must also consider the following in making final award decisions:

- equitable distribution of funds among organizations of different sizes and geographic locations;
- the extent to which an organization has received awards for the repair, renovation, construction, or replacement of academic facilities from any other federal funding source within the previous 5 years; and
- at least 12 percent of the funds available under the program must go to historically Black colleges and universities and other institutions with substantial minority enrollment.

Awards may range from $100,000 to $7 million. Total awards under this program to any eligible organization may not exceed $7 million during any five-year period.

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS $74,000,000

SUMMARY OF REQUEST

The FY 1991 Request for Scientific, Technological, and International Affairs (STIA) is $74.00 million, an increase of $10.53 million, or 16.6 percent over the FY 1990 Current Plan of $63.47 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science Resources Studies	$4.25	$6.00	$5.31	$5.99
Policy Research and Analysis	0.85	0.85	0.84	0.85
Research Initiation and Improvement	22.93	26.74	26.03	32.15
Industrial Science and Technological Innovation	19.05	21.46	20.05	22.93
International Cooperative Scientific Activities	11.22	12.27	11.24	12.08
Total, Activity	$58.31	$67.32	$63.47	$74.00

NSF ROLE

STIA is responsible for cross-disciplinary activities which at once satisfy requirements for scientific and technological excellence and broader objectives related to the national and international science and technology (S&T) infrastructure. STIA programs are often experimental in nature. Many are designed to promote interactions among academic institutions, federal agencies, State governments, private industry, nonprofit organizations, and foreign countries.

Programs within the Activity strengthen scientific and engineering research and education in the U.S.; provide information for policy formulation; monitor U.S. research and development (R&D) investment; initiate and support international cooperative research and education activities; and foster information exchange among U.S. and foreign scientists and engineers.

These diverse programmatic responsibilities are distributed among five organizational units:

- Data, information, and analyses on U.S. and international science and technology resources are developed within the Science Resources Studies (SRS) and Policy Research and Analysis (PRA) Subactivities. The ability to monitor and analyze strengths and weaknesses of the S&T system is critical to sound policy and programmatic development.

- Health of the U.S. S&T enterprise requires a strong human resource base. Research Initiation and Improvement (RII) programs develop these resources through increased education and research participation of underrepresented groups, institutions, and geographical regions;
- Research activities of small high-technology firms are promoted through the Small Business Innovation Research (SBIR) Program within the Industrial Science and Technological Innovation (ISTI) Subactivity. SBIR facilitates technological innovation and commercialization of research from the small business industrial sector; and,
- U.S. science and engineering is strengthened through cooperative research and education efforts with other countries. International Cooperative Scientific Activities (INT) promotes collaboration between U.S. researchers and their international colleagues, building on areas of mutual S&T strength and supporting U.S. foreign S&T policy objectives.

SRS and PRA are important to the S&T community for their ability to provide information on the number and characteristics of science and engineering personnel, R&D funding, and the characteristics of the academic infrastructure. The recent biennial survey series on academic facilities, for example, established a comprehensive national database on key quantitative and qualitative aspects of the university infrastructure. These data were used to develop the NSF Research Facilities Program.

International comparisons of S&T activities place this Nation's performance in context with its international competitors. Problems in data comparability make accurate comparisons difficult. A broad range of S&T personnel, funding, and input/output indicator information has been developed for five major industrialized countries (United States, France, West Germany, Japan, and the United Kingdom). Other countries are adopting NSF-developed data-handling techniques and information sources.

NSF has a legislative mandate to monitor the participation of minorities in science and engineering. Studies have shown continued underrepresentation; a decline in the total number of degrees awarded to blacks within the U.S. over the past decade; and poor retention rates throughout the educational pipeline. The new Research Careers for Minority Scholars (RCMS) Program, initiated within RII, encourages universities to develop innovative approaches to enhance the advancement of minorities from the undergraduate level through the attainment of the doctoral degree. The RII Experimental Program to Stimulate Competitive Research (EPSCoR), operating in 16 States and Puerto Rico, has been a successful catalyst in assisting underrepresented regions to build local S&T resources.

Along with 11 other research-oriented Federal agencies, NSF promotes the Small Business and Innovation Research (SBIR) Program, especially among minority- and women-owned firms. These awards were made in 28 States, within 26 disciplinary areas. Since its initiation at NSF in 1977, cumulative private investment and subsequent sales resulting from SBIR Phase I projects (product development, manufacturing, and marketing efforts) has exceeded $750 million.

U.S. industry competes in a global economy. Activities within the INT Subactivity provide the U.S. S&T community with research opportunities abroad. The basic-research agreement between the NSF and the Soviet Academy of Sciences, signed in May 1989, has created new opportunities for cooperation in mathematics, Arctic research, theoretical physics, geosciences, chemistry, life sciences, basic engineering research, and science policy. For the first time, U.S. and Soviet researchers can submit jointly initiated research proposals for competitive review. Recent visits of U.S. research teams to the site of the Armenian earthquake and to the Kamchatka Peninsula, one of the most volcanically active areas in the world, are early examples of rich research opportunities that are becoming available.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Science Resources Studies	$4.25	$6.00	$5.31	$-0.69	-11.5%
Policy Research and Analysis	0.85	0.85	0.84	-0.01	-1.2
Research Initiation and Improvement	22.93	26.74	26.03	-0.71	-2.7
Industrial Science and Technological Innovation	19.05	21.46	20.05	-1.41	-6.6
International Cooperative Scientific Activities	11.22	12.27	11.24	-1.03	-8.4
Total, Activity	$58.31	$67.32	$63.47	$-3.85	-5.7%

The FY 1990 Current Plan is $63.47 million, a decrease of $3.85 million, or 5.7 percent, from the FY 1990 Budget Request of $67.32 million. This represents an increase of $5.16 million, or 8.8 percent over FY 1989 levels.

The allocation of reductions across STIA Subactivities reflect programmatic priorities. In the RII Subactivity, EPSCoR and Individual and Group Support for Women and Minorities are protected at levels above specified across-the-board budget reductions. In the SRS Subactivity, data collection initiatives are protected to the extent possible. Funding reductions affect the following programs:

- In the ISTI Subactivity, the SBIR target is determined by the legislative formula.
- The INT Subactivity is held virtually constant at FY 1989 funding levels prohibiting planned expansion of certain Japanese and Pacific Rim programs. Flexibility to capitalize on rapidly expanding opportunities with the U.S.S.R. and Eastern Europe is limited.
- In the SRS Subactivity, redesign of the Scientific and Technical Personnel Data System and establishment of an undergraduate education database will be carried out at reduced levels.
- In the RII Subactivity, Individual and Group Support for Women and Minorities as well as Minority Institutional Development are protected to the extent possible. Fewer and/or smaller awards than planned, rather than any program changes, will absorb any decrease from the request level.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Science Resources Studies	$5.31	$5.99	$0.68	12.8%
Policy Research and Analysis	0.84	0.85	0.01	1.2
Research Initiation and Improvement	26.03	32.15	6.12	23.5
Industrial Science and Technological Innovation	20.05	22.93	2.88	14.4
International Cooperative Scientific Activities	11.24	12.08	0.84	7.5
Total, Activity	$63.47	$74.00	$10.53	16.6%

The FY 1991 Request for the Scientific, Technological, and International Affairs Activity is $74.00 million, or 16.6 percent above the FY 1990 Current Plan of $63.47 million. The FY 1991 Request incorporates the Foundation's three central budget themes:

RESEARCH AND FACILITIES:

In FY 1991, approximately 55 percent of the total STIA budget, or about $40.8 million, will support research across all NSF disciplinary areas, an increase of 11.8 percent over FY 1990. These awards, made primarily under the ISTI and INT Subactivities, meet dual objectives of supporting high-quality research in addition to promoting S&T activities within small high-technology companies or the international community, respectively.

- 240 awards, totaling $22.51 million, are expected to be made under the Small Business Innovation Research (SBIR) Program, administered by the ISTI Subactivity.
- A pilot College and University Innovation Research (CUIR) Program will be initiated within the ISTI Subactivity. The objective of CUIR is to stimulate faculty/small business entrepreneurial partnerships, facilitating commercialization of university research. In FY 1991, 16 awards are expected to be made with $0.42 million in STIA support with matching funds from NSF discipline-oriented activities.
- Nearly 450 awards are expected to be made in the INT Subactivity. In FY 1991, programmatic emphasis will be placed on cooperative scientific activities with the U.S.S.R. and Eastern Europe.

- Minority Research Centers of Excellence will be supported under the RII Subactivity at a level of approximately $5.80 million in FY 1991, unchanged from the FY 1990 level. Currently six centers have multi-year funding commitments of approximately $1.00 million annually to support research and train students. This program represents NSF's commitment to support center-based research in rapidly growing areas of critical national interest; to strengthen science and engineering research participation of leading minority institutions; and to attract talented minority students to science and engineering careers. In FY 1991, transfer of two existing centers to the MPS and BBS Activities will begin; competition for two to three new centers will be held within the RII Subactivity.

EDUCATION AND HUMAN RESOURCES:

In FY 1991, education and human resource development activities within STIA will be funded at a level of $33.20 million, approximately 44 percent of the total budget. Programmatic emphasis derives from the need to train adequate numbers of highly qualified scientists and engineers to meet demands of an increasingly technology-driven economy. The adequate supply of science and engineering talent to meet future demand depends on the attraction and retention of underrepresented groups in science and engineering careers. STIA contributes to the achievement of this latter objective through the following programs:

- Individual and Group Support for Women and Minorities under the RII Subactivity will receive $11.55 million in FY 1991, a 103 percent increase over FY 1990. The Research Careers for Minority Scholars (RCMS) Program will increase by 156 percent to $8.80 million. The Visiting Professorships for Women (VPW) Program, supporting advanced research opportunities and mentoring activities for women, will be increased by 23.6 percent to $2.75 million.

- The Experimental Program to Stimulate Competitive Research (EPSCoR) will be fully funded at $9.8 million in FY 1991. In FY 1991, the Program will remain active in 16 States and Puerto Rico.

- Intramural analyses and data collection activities under the PRA and SRS Subactivities will receive $6.84 million, a 11.2 percent increase over FY 1990. SRS assembles data from nearly 20 surveys which cover all sectors of employment and funding characteristics for science and engineering. SRS will receive virtually all the funding increase for these activities to continue implementation of the Scientific and Technical Personnel Data System (STPDS) and the undergraduate education data system. Both of these efforts are critical to setting the context within which Foundation programs operate and to monitoring human resource inputs to the S&T enterprise.

SCIENCE RESOURCES STUDIES..$5,990,000

SUMMARY OF REQUEST

The FY 1991 Request for Science Resources Studies (SRS) is $5.99 million, an increase of $0.68 million, or 12.8 percent over the FY 1990 Current Plan of $5.31 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Studies of Science and Engineering Resources	$4.25	$6.00	$5.31	$5.99

SCIENTIFIC OVERVIEW

The Science Resources Studies (SRS) Subactivity responds to the NSF legislative mandate to "provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and engineering resources, and to provide a source of information for policy formulation by other agencies of the Federal Government..." SRS surveys are a primary source of U.S. science and engineering statistics on people, R&D funding, and academic infrastructure. They form the basis for Congressionally-mandated reports such as Science and Engineering Indicators; Women and Minorities in Science and Engineering; Scientific and Engineering Research Facilities at Universities and Colleges; and Federal Obligations to Universities and Colleges.

Priority is given to development of an up-to-date, policy relevant, and high quality information base. This information fulfills needs of S&T decision-makers on a nationwide basis. SRS data and analyses address:

- Demographic, employment, and educational characteristics of the science and engineering population ;
- Undergraduate education, describing student characteristics, degree attainment, enrollments, and faculty in support of NSF and other Federal programmatic initiatives in this area;
- Federal, State, industrial, and, academic R&D expenditures;
- Output and impact indicators of science and technology;
- International comparisons of S&T resources data on personnel and expenditures; and
- Projections of the demand for and supply of science and engineering personnel.

Special ad hoc surveys also address topical issues related to science, engineering, and technology policy.

SRS coordinates its data collection activities with other Federal agencies to maximize coverage and prevent duplication of effort. The National Institutes of Health, National Endowment for the Humanities, and Departments of Education, Energy, and Agriculture help fund SRS-sponsored surveys. In addition, SRS supplements its own efforts with data from ongoing survey programs in other agencies, e.g., the Census Bureau, Bureau of Labor Statistics, Patent and Trademark Office, National Center for Education Statistics, Immigration and Naturalization Service, and the Office of Personnel Management.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Studies of Science and Engineering Resources	$4.25	$6.00	$5.31	$-0.69	-11.5%

The FY 1990 Current plan is $5.31 million, a decrease of $0.69 million, or 11.5 percent below the FY 1990 Budget Request of $6.00 million. Support of recurring survey activities will be maintained at previous levels. Redesigning the Scientific and Technical Personnel Data System (STPDS) will proceed at a reduced level of effort, still ensuring a solid base for operations during the nineties. Funding for the new Undergraduate Education Data System, which will provide information relevant to NSF program development, will be cut by more than one-half; full development will be deferred.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Studies of Science and Engineering Resources	$5.31	$5.99	$0.68	12.8%

The FY 1991 Request of $5.99 million represents a 12.8 percent increase over the FY 1990 Current Plan. SRS continues to place high priority on the existing science resources database and data quality activities. Electronic automation of databases, electronic dissemination of data and analyses, and development of projection models will be supported.

Continued emphasis will be placed on implementing the STPDS for the nineties. STPDS provides comprehensive data on the educational, demographic, and employment characteristics of the science and engineering population. The redesigned system will fill a major data gap on immigrant participation in U.S. S&T activities, as well as provide new information on employment dynamics. Undergraduate education data collection and analysis will be emphasized.

Development of comparable international data on the support and performance of R&D activities for the U.S. and its major competitors is critical in the current global economy. Work will continue on collection and dissemination of data on the Soviet Union, Japan, Western Europe, and other selected countries.

POLICY RESEARCH AND ANALYSIS..$850,000

SUMMARY OF REQUEST

The FY 1991 Request for Policy Research and Analysis (PRA) is $0.85 million, an increase of $0.01 million, or 1.2 percent, over the FY 1990 Current Plan of $0.84 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Policy Research and Analysis	$0.85	$0.85	$0.84	$0.85

SCIENTIFIC OVERVIEW

The Policy Research and Analysis (PRA) Subactivity provides analyses of national science and technology (S&T) policy issues. Studies focus on:

- The role of academic research in the changing economic and technological environment;
- The economics of U.S. academic research activity;
- The future supply of scientists and engineers, i.e., the science and engineering pipeline; and
- Other special policy issues.

PRA is developing a large in-house electronic database which includes information on science and engineering education, personnel, and expenditures obtained from SRS, other Federal agencies, and professional organizations. This database management system is designed to facilitate analyses in support of S&T policy formulation.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Policy Research and Analysis	$0.85	$0.85	$0.84	$-0.01	-1.2%

The FY 1990 Current Plan is $0.84 million, a decrease of $.01 million, or 1.2 percent, from the FY 1990 Budget Request of $0.85 million. This level enables PRA to carry out its full range of activities.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Policy Research and Analysis	$0.84	$0.85	$0.01	1.2%

PRA will continue to conduct intramural studies which directly support issues of interest to NSF and the National Science Board and to develop its electronic database. Studies will focus on the changing role of academic research institutions and on factors and Federal programs that will affect the future supply of scientists and engineers. PRA will also conduct specialized analyses that support program development and evaluation in other parts of the Foundation.

RESEARCH INITIATION AND IMPROVEMENT............................$32,150,000

SUMMARY OF REQUEST

The FY 1991 Request for Research Initiation and Improvement (RII) is $32.15 million, an increase of $6.12 million, or 23.5 percent, over the FY 1990 Current Plan of $26.03 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Individual and Group Support for Women and Minorities	$4.21	$5.95	$5.68	$11.55
Minority Institutional Development Support	10.63	10.79	10.55	10.80
Experimental Program to Stimulate Competitive Research	8.09	10.00	9.80	9.80
Total, Subactivity	$22.93	$26.74	$26.03	$32.15

SCIENTIFIC OVERVIEW

The RII Subactivity supports programs that strengthen the Nation's human, institutional, and regional science and technology (S&T) resource base. Programs are conducted in cooperation with NSF discipline-oriented activities. The objectives of this Subactivity are to:

- Remove barriers that inhibit full participation of individuals, institutions, and regions in the Nation's S&T effort.
- Improve access to S&T resources by institutions and States whose participation and performance in science and engineering research and education activities are below the national average;
- Increase research opportunities for faculty--especially women, minorities, and persons with disabilities--as well as for faculty from predominantly undergraduate institutions so that they may participate more fully in the Nation's S&T enterprise; and,
- Strengthen and diversify the human resource and institutional base on which the Nation's performance in science and technology depend.

RII programs respond to the National Science Foundation Authorization and Science and Engineering Equal Opportunities Act (P.L. 99-159), which commits NSF to promoting full development and use of the scientific talent and technical skills of men and women of all ethnic, racial, and economic backgrounds in all regions of the Nation, and to Presidential Executive Order

12677, which mandates the strengthening of capabilities of historically black colleges and universities.

RII is directly responsible for five programs:

Individual and Group Support for Minorities and Women:

- Research Careers for Minority Scholars (RCMS) is a comprehensive program of student support, faculty incentives, mentoring, and coordinated academic enrichment and research activities. The goal of the program is to increase retention of talented minority students through undergraduate and graduate study in the sciences and engineering.

- Visiting Professorships for Women (VPW) provides support for women scientists and engineers to conduct research and to serve as visible role models for women students who are pursuing science and engineering research careers.

Minority Institutional Development Support Programs:

- Research Improvement in Minority Institutions (RIMI) promotes improvements to research environments at predominantly minority colleges and universities, as well as other institutions with significant minority enrollment. The program provides support for faculty research, research equipment, and increased student involvement in research projects.
- Minority Research Centers of Excellence (MRCE) are targeted on selected minority institutions with established research bases. The Program provides support and incentives to design and implement long-range plans which will significantly upgrade research and education capabilities in NSF-supported fields.

Experimental Program to Stimulate Competitive Research (EPSCoR):

- EPSCoR is designed to broaden the geographic distribution of research opportunities. The program acts as a catalyst to develop long-term improvements in the infrastructure for science and engineering. Participant states play a lead role in designing specific strategies and mechanisms to achieve this goal.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Individual and Group Support for Women and Minorities	$4.21	$5.95	$5.68	$-0.27	-4.5%
Minority Institutional Development Support	10.63	10.79	10.55	-0.24	-2.2
Experimental Program to Stimulate Competitive Research	8.09	10.00	9.80	-0.20	-2.0
Total, Subactivity	$22.93	$26.74	$26.03	$-0.71	-2.7%

The FY 1990 Current Plan is $26.03 million, a decrease of $0.71 million, or 2.7 percent, below the FY 1990 Budget Request of $26.74 million, but represents a $3.1 million increase, or 13.5 percent, over FY 1989.

In establishing the Current Plan, the Foundation gave priority to the RII programs for women and minorities. The planned expansion of the RCMS program will be maintained and funding for Visiting Professorships for Women (VPW). Minority Research Centers of Excellence (MRCE), and Research Improvement in Minority Institutions (RIMI) will be held close to request levels.

Funding for the EPSCoR Program was protected by Congress and will be funded slightly above that specified level.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Individual and Group Support for Women and Minorities	$5.68	$11.55	$5.87	103.3%
Minority Institutional Development Support	10.55	10.80	0.25	2.4
Experimental Program to Stimulate Competitive Research	9.80	9.80	0.00	0.0
Total, Subactivity	$26.03	$32.15	$6.12	23.5%

The FY 1991 Budget Request demonstrates strong commitment to women and minorities as well as infrastructure development programs within the RII subactivity.

Within the Individual and Group Support to Women and Minorities program element, funding for RCMS will increase by $5.4 million, or 156 percent, and funding for the VPW Program will increase by $0.53 million, or 23.6 percent.

- The achievements of the RCMS program--innovative minority retention programs and the support of minority scholars throughout their undergraduate studies in science and engineering fields--provide an important focus for other Foundation-wide initiatives to increase minority participation in research. The FY 1991 increase will allow continuation of approximately 20 on-going projects and initiation of about 25 new RCMS projects. At $8.8 million, the program will support approximately 900 minority undergraduate students, and act as a catalyst for improvements in the undergraduate environment in 45 institutions.
- The VPW Program will increase award size to support mentoring activities in home institutions.

Within the Minority and Institution Development Support program element, funding for the RIMI Program will increase $0.25 million, or 5.3 percent, to provide the capability to respond to additional proposal pressure. Funding for the MRCE Program will remain constant. In FY 1991, transfer of responsibility for funding and continued development of the Howard University and the Meharry Medical College Centers will be made to the MPS and BBS Activities, respectively. Funds made available as a result of this transfer will support a competition for two to three new centers.

The EPSCoR Program will be maintained at the FY 1990 funding level of $9.8 million. The program will continue to focus on areas in which it has already achieved noted success: organizing State-wide authorities that enhance S&T activities; increasing the number of proposals which pass merit evaluation in Federal research-funding programs; and improving the quality of science and engineering education. This funding level will continue to allow EPSCoR to be active in 16 states and in Puerto Rico.

In keeping with RII's focus on increasing the representation of women and minorities in science and engineering fields, this Subactivity will also coordinate two new NSF-wide programs, Alliances for Minority Participation and Faculty Awards for Women.

INDUSTRIAL SCIENCE AND TECHNOLOGICAL INNOVATION...$22,930,000

SUMMARY OF REQUEST

The FY 1991 Request for Industrial Science and Technological Innovation (ISTI) is $22.93 million, an increase of $2.88 million, or 14.4 percent over the FY 1990 Current Plan of $20.05 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Small Business Innovation Research	$19.05	$21.46	$20.05	$22.51
College and University Innovation Research	—	—	—	0.42
Total, Subactivity	$19.05	$21.46	$20.05	$22.93

SCIENTIFIC OVERVIEW

The ISTI Subactivity has primary responsibility for the Small Business Innovation Research (SBIR) Program. SBIR funds small R&D-based and product-based companies to perform research leading to rapid commercialization of new products and processes.

The SBIR Program was developed by NSF in 1977. The concept was subsequently incorporated into legislation (Small Business Innovation Development Act, P.L. 99-443) and expanded to 11 other research-oriented Federal agencies. The goals of the Program are:

- Support of high-quality research in advanced applications across all NSF fields of science and engineering;
- Stimulation of technological innovation in the private sector;
- Increased commercial application of NSF-sponsored research; and,
- Increased participation by firms owned by women, minorities, and persons with disabilities.

SBIR is a three-phase program: Phase I explores concept feasibility; Phase II follows with research leading to development of a commercializable prototype; and Phase III continues technology development and commercialization. The SBIR Program at NSF concentrates on the first two research phases, with proposals screened according to technical merit. Non-Federal venture capital funding is required for the technology development in Phase III.

NSF continues its lead role among Federal agencies in promoting the SBIR Program. NSF and the other Federal agencies sponsor two conferences annually to describe SBIR opportunities to potential participants, typically over 1,200 firms. In 1989, ISTI staff assisted several local governments in promoting small business-related activities for economic development. Such regional outreach activities are expected to increase.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Small Business Innovation Research	$19.05	$21.46	$20.05	$-1.41	-6.6%
College and University Innovation Research	—	—	—	—	—
Total, Subactivity	$19.05	$21.46	$20.05	$-1.41	-6.6%

The FY 1990 Current Plan is $20.05 million, a decrease of $1.41 million, or 6.6 percent, below the FY 1990 Budget Request, but an increase of $1.00 million over FY 1989. The FY 1990 Current Plan is legislatively determined as 1.25 percent of the NSF extramural research budget.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Small Business Innovation Research	$20.05	$22.51	2.46	12.3%
College and University Innovation Research	—	0.42	0.42	—
Total, Subactivity	$20.05	$22.93	$2.88	14.4%

The SBIR Program will continue to support quality research proposals in advanced science and engineering concepts from high-technology small business firms. Successful SBIR projects result in applications of technologies which contribute to both the competitive position and economic performance of the Nation. The increase of $2.46 million maintains the SBIR Program at 1.25 percent of the Foundation's extramural research budget. More than 1,625 proposals, across all NSF-supported disciplines, are expected to be submitted under to the Program in FY 1991.

In FY 1989, Congress requested that the Foundation submit a report on how to assist the academic community in pursuing high quality research of economic potential (NSF Authorization Act of 1989, Section 114). In FY 1991, NSF intends to initiate the pilot College and University Innovation Research (CUIR) Program to facilitate development of new high-technology products derived from academic research results. CUIR will be modeled after the three-phased SBIR Program. NSF will support Phase I feasibility projects at colleges and universities; Phase II research, carried out in academic institutions and the private sector, will be handed over to Federal mission agencies; and Phase III research will require non-Federal venture capital. CUIR will encourage development of linkages between universities and private industry; leverage Federal funds with private sector capital; and stimulate entrepreneurship.

In FY 1991, 16 awards are expected to be made with $0.42 million in STIA support with matching funds from NSF-discipline-oriented activities.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES..$12,080,000

SUMMARY OF REQUEST

The FY 1991 Request for International Cooperative Scientific Activities (INT) is $12.08 million, an increase of $0.84 million, or 7.5 percent over the FY 1990 Current Plan of $11.24 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
International Cooperative Scientific Activities	$11.22	$12.27	$11.24	$12.08

SCIENTIFIC OVERVIEW

The growth of science and technology internationally and its direct relationship to overall economic competitiveness have increased the need to assure that U.S. scientists and engineers are aware of and effectively linked with scientific developments and centers of excellence abroad.

The INT Subactivity supports international cooperative programs that benefit the U.S. science and engineering enterprise. Objectives of the program are to:

- Increase the access of U.S. scientists and engineers to research environments and facilities abroad;
- Coordinate NSF participation in cooperative scientific agreements with over 30 countries, supporting high priority S&T initiatives with Japan and the European Community, as well as the Soviet Union, India, Brazil, and Pacific Rim countries;
- Assist the Executive Office of the President and the Department of State in carrying out U.S. foreign policy related to science and technology; and,
- Manage NSF participation in international and multilateral organizations, e.g., the International Council of Scientific Unions (ICSU), as well as support research projects in organizations such as the International Institute for Applied Systems Analysis (IIASA).

Cooperative S&T opportunities continue to expand rapidly, linking U.S. and foreign researchers in areas of mutual strength and interest. For example, the NSF Japan Initiative provides U.S. researchers access to academic, government, and industrial laboratories in that country. This initiative, which includes language study, long-term (greater than six-month) research stays, and surveys of Japanese state-of-the-art in specific disciplines, seeks to facilitate diffusion of technology from Japanese to U.S. laboratories. In the Soviet Union and Eastern Europe the changing political environment provides unprecedented access to centers of expertise, unique facilities, and research sites.

Information gathering and analytic activities within INT are being emphasized. Technological developments in some 50 countries and organizations are monitored and analyzed. Information is disseminated to U.S. policy analysts and researchers through a variety of mechanisms. The publication, *International S&T Insight*, provides information on foreign policies, research development and programs, as well as leading areas of international cooperation. A new electronic Science and Technology Information System (STIS) will provide timely access to such information.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
International Cooperative Scientific Activities	$11.22	$12.27	$11.24	$-1.03	-8.4%

The FY 1990 Current Plan is $11.24 million, a decrease of $1.03 million, or 8.4 percent, from the FY 1990 Budget Request of $12.27 million. The funding reduction will slow the expansion of programs to promote access to Japanese academic, industrial, and government laboratories and will inhibit research opportunities in Pacific Rim countries. Support of activities to enhance the international background of U.S. science and engineering undergraduate students will be curtailed. Flexibility to capitalize on expanding collaborative research opportunities with the Soviet Union and Eastern Europe is limited.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
International Cooperative Scientific Activities	$11.24	$12.08	$0.84	7.5%

The FY 1991 Request represents an increase of $0.84 million over the FY 1990 Current Plan to:

- Fully capitalize on changing political environments within Eastern European countries by linking researchers through competitive grant programs. The combined effect of bilateral agreements provides American researchers greater access to entire regions which possess distinct natural conditions, long-standing academic traditions, and environmentally damaged ecosystems.
- Implement the Memorandum of Understanding (MOU) between the Foundation and the U.S.S.R. Academy of Sciences signed in May 1989. While basic research proposals in the seven areas of cooperation will be funded through NSF discipline-oriented activities, INT shares with SRS responsibility for cooperation in science policy. Special emphasis will be placed on extensive data definition, collection, and analytic efforts which will facilitate cross-country comparisons of R&D inputs and performance. INT will also support project development travel and workshops that will contribute to overall definition and growth of the U.S./U.S.S.R. program.

PROGRAM DEVELOPMENT AND MANAGEMENT $102,500,000

SUMMARY OF REQUEST

The FY 1991 Request for Program Development and Management (PD&M) Activity is $102.50 million, an increase of $6.12 million, or 6.3%, over the FY 1990 Current Plan of $96.38 million.

Summary of Request

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Estimate
(Funds in Millions of Dollars)				
Personnel Compensation & Benefits *	$62.12	$65.27	$64.60	$69.00
General Operating Expenses *	26.94	36.08	31.78	33.50
PD&M Expenses of the Inspector General	2.22	2.65	NA	NA
Total	$91.28	$104.00	$96.38	$102.50
FULL-TIME EQUIVALENT EMPLOYMENT:				
Full-Time Equivalent (FTE) *	1,171	1,230	1,195	1,225

* FY 1990 Plan and FY 1991 Estimate excludes Office of the Inspector General (OIG) which is funded under a separate appropriation. The Expenses of the OIG were funded through the PD&M activity in FY 1989.

DESCRIPTION

The Program Development and Management Activity (PD&M) includes funds for staff salaries, travel, rent, equipment, administrative contractual services and other operating expenses necessary for effective and efficient operation and management of the NSF. Costs associated with relocation of NSF headquarters are requested under a separate Activity.

NSF is organized into seven program directorates, an Administration directorate, six staff offices, Office of the Inspector General, and the National Science Board Office. The staff offices are: 1) Budget and Control, 2) General Counsel, 3) Information Systems, 4) Legislative and Public Affairs, 5) Science and Technology Centers, and 6) Research Facilities Office. The National Science Board Office provides for the analytical support of the Board and coordinates its activities with staff throughout the Foundation. Additional staff support to the Board is provided by other Foundation staff on an ad hoc basis.

The direct operating expenses of the Office of the Inspector General are funded through a separate appropriation. All other organizations are funded through the PD&M activity within the Research and Related Activities appropriation.

ACHIEVEMENTS

NSF continues to focus attention on developing information management policy and improving business practices and information flows, resulting in the following accomplishments:

- Developed and implemented decentralized automated procedures for training requests and personnel actions which are entered and approved on-line, with payment being made through interface with the financial system. This results in improved data entry, report generation, and audit trail, as well as the elimination of paperwork. Several agencies have investigated the training system as a prototype for their own applications.
- Developed and implemented a system for the automatic (electronic) processing of increments due on continuing research grants. As a result of this automation, it is estimated that in Fiscal Year 1990, 3,500 award actions will be electronically processed, hence replacing paper transactions.
- Designed and installed nearly 300 systems furniture workstations at NSF. This has resulted in improved utilization of space (housing additional staff without acquiring new space) and a more efficient work environment for many NSF staff members.
- Continued software development on a mainframe computer which will greatly improve data retrieval capabilities and reduce report processing time. A central database was developed and the conversion of existing management systems to the new environment was continued during the year.

STAFFING

FTE's *

	FY 1989 Actual	FY 1990 Request	FY 1990 Plan	FY 1991 Estimate	Difference FY 91/90
Administration	211	205	206	207	1
Biological, Behavioral and Social Science	146	152	152	156	4
Computer and Information Science and Engineering	61	70	65	68	3
Engineering	102	115	106	109	3
Geosciences	132	145	142	147	5
Mathematical and Physical Sciences	117	134	126	129	3
Scientific, Technological, and International Affairs	146	149	147	149	2
Science and Engineering Education	74	78	83	90	7
Staff Offices of the Director	163	159	168	170	2
Inspector General	19	23	0	0	0
TOTAL	1,171	1,230	1,195	1,225	30

* FY 1990 Plan and FY 1991 Estimate excludes Office of the Inspector General which is funded under a separate appropriation.

Changes in FY 1990 FTE Allocations

In FY 1990, there is a reduction of 35 FTE from the FY 1990 request. The reduction from 1,230 FTE to 1,195 FTE is due principally to the transfer of 25 FTE to the Office of the Inspector General which is funded under a separate appropriation in FY 1990. The decrease from the request in the FY 1990 current plan for PD&M results in the reduction of the additional 10 FTE. The current annualized FTE utilization rate is 1,198 FTE. The high rate is due in part to recruiting efforts enhanced by the ability to more closely match academic and private sector compensation afforded by a section of the NSF Authorization Act of 1989.

Comparison of FY 1990 and FY 1991 FTE

Staffing will increase by 30 Full-Time Equivalent staff-years (FTE) from the funded level of 1,195 FTE in 1990 to 1,225 FTE in 1991. The increase will consist primarily of scientists and engineers. Highly qualified professionals are needed to support the growth in the size and number of research and education programs. Further, the investment in office automation and information management systems has increased the productivity of clerical and technical personnel. Therefore, the staff will consist of a higher ratio of professional to clerical employees than currently exists.

The staff increase will be distributed to research areas having responsibility for managing initiatives and experiencing workload increases due to programmatic growth. Continued recruiting efforts and pay flexibility should allow NSF to continue full utilization of requested FTEs in 1991.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(MILLIONS OF DOLLARS)

	FY 1990 Request	FY 1990 Plan	Change	
			Amount	Percent
Personnel Compensation and Benefits *	$65.27	$64.60	-0.67	-1.0%
General Operating Expenses *				
Travel	3.72	3.40	-0.32	-8.6
Information Systems	10.95	8.67	-2.28	-20.8
Other General Expenses	21.41	19.71	-1.70	-7.9
Subtotal, General Operating Expenses	36.08	31.78	-4.30	-11.9
PD&M Expenses of the Inspector General	2.65	NA	-2.65	NA
Total	$104.00	$96.38	-7.62	-7.3%

* FY 1990 Request and FY 1990 Plan excludes Office of the Inspector General, which is funded under a separate appropriation.

Personnel Compensation and Benefits - The difference between the FY 1990 budget request of $65.27 million and FY 1990 current plan of $64.6 million for personnel compensation and benefits is a net decrease of $0.67 million. This decrease is associated with the reduced FY 1990 FTE level of 1,195. An additional $1.7 million required to fund the January 1990 pay raise, which was not included in the FY 1990 request, will be absorbed.

Travel - The FY 1990 current plan for travel has been reduced by $320,000 from the FY 1990 budget request. This amount is consistent with a decrease in funded FTE and with the transfer of funding for the Office of the Inspector General to a separate appropriation in FY 1990.

The estimate for Transportation of Things will increase $120,000 over the FY 1990 request, consistent with actual FY 1989 costs experienced for this function. The higher cost is due to the increased number of visiting scientists and engineers employed by the Foundation. The projected increase for this function is contained within the estimated costs of administrative contracts in the President's Budget. Accordingly, both estimates have been revised in the tables accompanying this narrative.

General Expenses - The FY 1990 current plan for general operating expenses has been reduced by $1.70 million from the FY 1990 budget request. Most of the decrease will be accommodated through reduction in administrative contracts ($553,000) and by deferring variable costs such as furniture and office and printing equipment.

Information Systems - The FY 1990 current plan for information systems has been reduced $2.28 million by reducing contracts for the design and development of information systems for the mainframe as well as the personal computer-based local area network. The scheduled replacement and upgrade of existing microcomputers and software which are near the end of their replacement life cycle has also been deferred.

1991 BUDGET HIGHLIGHTS

SUMMARY

The $102.5 million requested for the PD&M Activity continues to be less than 5% of the total budget request for the Foundation. Of the $6.12 million increase, 72% ($4.40 million) is for personnel compensation and benefits necessary to fully fund the requested level of 1,225 FTE in FY 1991.

The $1.7 million balance of the increase is related to a large number of operating expenses including program travel (an increase of $200,000), rent, communications and postage (an increase of $445,000), training, administrative, operations and maintenance contracts ($559,000), and upgraded furniture and ADP equipment ($453,000). Specific increases by major object class are explained in the following sections:

PERSONNEL COMPENSATION AND BENEFITS

	FY 1989 Actual	FY 1990 Request	FY 1990 Plan	FY 1991 Estimate	Difference FY 91/90
Personnel Compensation*					
Full Time Equivalent	$50,889,322	$54,333,000	$53,079,000	$56,750,000	$3,671,000
Other Personnel Compensation	2,644,469	2,200,000	2,200,000	2,400,000	200,000
NSB and Advisors	368,416	350,000	350,000	350,000	0
Subtotal, Personnel Compensation	53,902,207	56,883,000	55,629,000	59,500,000	3,871,000
Personnel Benefits*					
Employer Contributions: Health Insurance, Retirement, FICA etc.	8,105,349	8,256,000	8,841,000	9,370,000	529,000
Other Personnel Benefits	112,805	130,000	130,000	130,000	0
Subtotal, Personnel Benefits	8,218,154	8,386,000	8,971,000	9,500,000	529,000
TOTAL PERSONNEL COMPENSATION AND BENEFITS	$62,120,361	$65,269,000	$64,600,000	$69,000,000	$4,400,000

* All amounts exclude Office of the Inspector General which is funded under a separate appropriation in fiscal years 1990 and 1991.

In FY 1991, Personnel Compensation and Benefits costs are estimated at $69.00 million an increase of $4.40 million over the FY 1990 Current Plan of $64.6 million. The increase requested for salaries and benefits in FY 1991 reflects the full-year cost of the January 1990 government-wide pay raise, not funded in FY 1990 ($0.50 million); the cost of the SES pay raises effective in

1991 ($2.0 million); and the cost of 30 additional FTE staff years needed in FY 1991 ($1.9 million).

The request also reflects the cost of increasing the number of professionals, and increases associated with performance and incentive awards. The increased ability to match compensation and benefits of visiting professional staff recruited from the academic and private sector should make it possible to fully utilize 1,225 FTE in FY 1991.

The costs of Advisory and Assistance Services required by the Foundation to provide advice, counsel, critical review and recommendations concerning specific scientific and administrative activities are included within the total cost of personnel compensation. These costs ($350,000) are expected to remain relatively constant through FY 1991.

TRAVEL

The request for travel in FY 1991 is increased to $3.60 million, $200,000 above the FY 1990 current plan. This increase will cover increased airfare and per diem rates as well as site visits associated with requested programmatic increases.

TRAVEL *

	FY 1989 Actual	FY 1990 Request	FY 1990 Plan	FY 1991 Estimate	Difference FY 91/90
Administration	$122,616	$150,000	$135,000	$140,000	$5,000
Biological, Behavioral and Social Science	343,928	390,000	400,000	425,000	25,000
Computer and Information Science and Engineering	211,976	305,000	245,000	260,000	15,000
Engineering	405,911	510,000	455,000	485,000	30,000
Geosciences	514,361	613,000	610,000	640,000	30,000
Mathematical and Physical Sciences	443,338	530,000	525,000	550,000	25,000
Scientific, Technological, and International Affairs	264,445	460,000	325,000	345,000	20,000
Science and Engineering Education	170,365	225,000	215,000	245,000	30,000
Staff Offices of the Director	422,248	537,000	490,000	510,000	20,000
TOTAL TRAVEL	$2,899,208	$3,720,000	$3,400,000	$3,600,000	$200,000

* FY 1989 Actual, FY 1990 Request, FY 1990 Plan and FY 1991 Request columns exclude Office of the Inspector General which is funded under a separate appropriation in fiscal years 1990 and 1991.

GENERAL OPERATING EXPENSES (Includes Travel)*

	FY 1989 Actual	FY 1990 Request	FY 1990 Plan	FY 1991 Estimate	Difference FY 91/90
Travel	$2,899,208	$3,720,000	$3,400,000	$3,600,000	$200,000
Transportation of Things	321,636	230,000	350,000	400,000	50,000
Rents and Communications:					
Office Space Rentals	7,634,852	8,055,000	8,055,000	8,200,000	145,000
Data Processing Equipment ..	0	10,000	10,000	10,000	0
Other Rentals	78,983	250,000	150,000	150,000	0
Telephone, Telegraph, Postage	2,914,219	3,580,000	3,420,000	3,720,000	300,000
Subtotal, Rents & Comm. ..	10,628,054	11,895,000	11,635,000	12,080,000	445,000
Printing and Reproduction	659,435	820,000	820,000	820,000	0
Other Contractual Services:					
Administrative Contracts	3,774,259	4,814,000	4,261,000	4,470,000	209,000
Audit Services	0	0	0	0	0
DP Operations & Maintenance	2,401,169	2,720,000	3,150,000	3,450,000	300,000
DP Software Development ...	1,210,977	2,825,000	1,800,000	1,800,000	0
Employee Training	402,727	600,000	550,000	600,000	50,000
Subtotal, Other Contractual Services	7,789,132	10,959,000	9,761,000	10,320,000	559,000
Supplies and Materials:					
Office & Printing Supplies	463,556	837,000	795,000	800,000	5,000
Data Processing Supplies	90,617	40,000	95,000	100,000	5,000
Subtotal, Supplies and Materials	554,173	877,000	890,000	900,000	10,000
Equipment:					
Administrative Services Equip .	1,041,592	2,190,000	1,280,000	1,533,000	253,000
Data Processing Equipment ..	3,049,047	5,360,000	3,617,000	3,817,000	200,000
Subtotal, Equipment	4,090,639	7,550,000	4,897,000	5,350,000	453,000
Grants, Subsidies and Contributions:					
Award Recipients	4,486	30,000	30,000	30,000	0
Total, Other Expenses	$26,946,763	$36,081,000	$31,783,000	$33,500,000	$1,717,000

---

* FY 1989 Actual, FY 1990 Request, FY 1990 Plan and FY 1991 Request columns exclude Office of the Inspector General which is funded under a separate appropriation in fiscal years 1990 and 1991.

Other General Operating Expenses

The costs for Transportation of Things will increase $50,000 as a result of the increased employment of visiting scientist and engineers. This estimate has been revised since the development of the President's Budget. The planned increase had previously been displayed within the estimated cost of administrative contracts.

Office space rentals will require an additional $145,000 based on rates determined by the General Services Administration (GSA) to fund the amount of space currently occupied.

Telephone, Telegraph, Cable and Postage is increased by $300,000. Replacement and upgrade of telephone equipment will cost $60,000. Other increases for telecommunications ($145,000) and postage ($95,000) are due to a combination of rate increases and increased usage associated with growth in the number of proposals and awards as well as with increased demand from the scientific community for program announcements and program information.

Printing and Reproduction are expected to remain constant.

Other Contractual Services increase by $559,000.

- Administrative contracts increases by $209,000. This increase provides funding for current levels of contract services in the mail and supply rooms, copy room, and warehouse facility.
- Employee training increases $50,000 to cover increases for managerial, professional and administrative training needed to maintain employee skills.

Administrative Services Equipment increases by $253,000. This increase includes the acquisition of new high speed typesetting and collating equipment, desktop publishing equipment and additional systems furniture for existing space to accommodate staff increases.

Information Systems Contracts and associated items will be explained in the following section.

INFORMATION SYSTEMS

	FY 1989 Actual	FY 1990 Request	FY 1990 Plan	FY 1991 Estimate	Difference FY 91/90
Data Processing Equipment Rental	$0	$10,000	$10,000	$10,000	$0
Data Processing Operations & Maint	2,401,169	2,720,000	3,150,000	3,450,000	300,000
Data Processing Software Develop	1,210,977	2,825,000	1,800,000	1,800,000	0
Subtotal, DP Contracts	3,612,146	5,545,000	4,950,000	5,250,000	300,000
Data Processing Supplies	90,617	40,000	95,000	100,000	5,000
Data Processing Equipment	3,049,047	5,360,000	3,617,000	3,817,000	200,000
Total	$6,751,810	$10,955,000	$8,672,000	$9,177,000	$505,000

Data Processing Equipment Rentals provides funds for the lease of hardware, software, and communications equipment used in the NSF computer facility. Rental costs will not increase in FY 1991.

Data Processing Operations and Maintenance provides for:

- Operations of the Central computer facility on a 24 hour- a-day, seven days a week basis;
- Technical support and guidance in the use of information systems and the application of ADP office automation and technology;
- Maintenance of all central computer and communication equipment, local area network backbone and related hardware and software; and
- Maintenance of distributed equipment including personal computers, workstations and local area network components.

Data Processing Operations and Maintenance will increase by $300,000, to provide increased support for electronic mail, distributed applications and the mainframe systems ($210,000); cover incremental cost increases in the facility management contract and in maintenance contracts for the central systems ($90,000). Maintenance costs on personal computers are expected to remain constant.

Data Processing Software Development provides funds for contractors to design and develop complex, efficient information systems for both the mainframe and the distributed environments. The FY 1991 request includes no increase over the FY 1990 plan for this function.

Data Processing Supplies funds are required to purchase those expendable materials used in the NSF computer facility not provided by the facility management contractor. A minimal increase in the cost of these supplies is anticipated.

Data Processing Equipment provides funds for:

- Lease/purchase costs associated with the acquisition of the mainframe and related hardware and software;
- Local area network components and data communications equipment; and
- Advanced and replacement personal computer workstations, enhancements to current distributed computer systems (e.g. expansion boards, memory, printers, etc.) and software.

The increase of $200,000 covers: contractual increases in payments for software licenses ($35,000), upgrades to storage devices ($20,000), enhancements to Local Area Network and Electronic Mail Communication equipment for more efficient connectivity to the mainframe ($110,000), and additional equipment for technology assessment ($35,000).

PERSONNEL SUMMARY *

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Estimate
Total Compensable Workyears:	1,191	1,199	1,229
Full-Time Equivalent Employment	1,171	1,195	1,225
FTE Overtime and Holiday Hours	5	4	4
Other Full-Time Equivalent Staff Years	15	0	0
Average GS Grade	9.20	9.29	9.33
Average Salary	$43,773	$44,710	$46,612

* FY 1990 and FY 1991 excludes Office of the Inspector General which is funded under a separate appropriation.

Detail of Permanent Positions *

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Estimate
Executive Level II	1	1	1
Executive Level III	1	1	1
Subtotal	2	2	2
ES-6	13	13	13
ES-5	17	14	14
ES-4	64	63	63
ES-3	6	10	10
ES-2	4	6	6
ES-1	1	3	3
Subtotal	95	109	109
AD	163	162	167
GS/GM-15	86	84	86
GS/GM-14	78	74	74
GS/GM-13	72	67	70
GS-12	59	58	59
GS-11	49	49	52
GS-10	11	11	10
GS-9	50	50	52
GS-8	77	75	73
GS-7	93	87	88
GS-6	79	78	79
GS-5	63	58	58
GS-4	60	55	55
GS-3	27	24	24
GS-2	10	9	9
Subtotal	814	779	789
Ungraded	6	6	6
Total Permanent Positions	1,080	1,058	1,073

* FY 1990 and FY 1991 excludes Office of the Inspector General which is funded under a separate appropriation.

The table showing the detail of permanent positions is a summary of Permanent Positions as of the end of FY 1989 and estimated to be filled at the end of FY 1990 and FY 1991. OMB Circular NO. A-11 (Section 51.2) defines "permanent positions" as those which are occupied or to be occupied by full-time employees with permanent appointments.

NSF HEADQUARTERS RELOCATION $5,500,000

SUMMARY OF REQUEST

The request for funding the first major phase of the NSF relocation is $5.5 million in FY 1991. A separate Activity is proposed as costs related to relocation are not part of the Foundation's normal operating expenses. Also, relocation cost projections and schedules are highly variable, and treatment as a separate Activity provides funding flexibility unavailable within the PD&M Activity. This Activity is temporary, and should not extend beyond FY 1994 under the current planning schedule.

(Millions of Dollars)

Activity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Headquarters Relocation	$0.00	$0.00	$0.00	$5.50
Total	$0.00	$0.00	$0.00	$5.50

BACKGROUND

The National Science Foundation is in the process of consolidating its two office facilities into a single facility in the Washington Metropolitan Area. In addition to accommodating staff levels needed to support the Foundation's programs, the new facility will allow greater flexibility to accommodate organizational changes, provide expanded conferencing facilities for advisory committee and panel review meetings, meet NSF's rapidly increasing needs for electronic cabling and networking, and improve the overall quality and appearance of its space. The site selection and lease award will occur in the spring of 1990 and it will take about two years to complete construction. The move to the new building should begin in the summer of 1992 and be complete by September of that year.

COMPLETED MILESTONES

The formal relocation process began two and one-half years ago, on June 30, 1987, when NSF submitted a "Request for Space" to the General Services Administration (GSA) for the relocation and consolidation of NSF's facilities. On February 5, 1988, GSA submitted our prospectus to the Office of Management and Budget (OMB) for approval. In August 1988, OMB approved NSF's prospectus, and forwarded it to the House Committee on Public Works and Transportation which approved it on October 13, 1988. During this time, Ellerbe/HOK, our architectural and engineering contractors, conducted a facility requirements study and produced a Facility Master Plan which outlined our technical requirements. Once Congress had approved our prospectus, GSA could officially begin the acquisition process.

On December 19, 1988, GSA issued a public advertisement for the NSF acquisition. In March, 1989, our Solicitation for Offers (SFO) package was issued and distributed to over 80 interested developers. The responses to the SFO were received on June 28, 1989, and the evaluation of offers began in July 1989.

FUTURE MILESTONES

January 1990	-	Competitive range set.
February 1990	-	Receipt of "Best and Final" Offers.
Feb-Mar. 1990	-	Lease negotiations and site selection.
Mar-Apr. 1990	-	Lease award/public announcement of site.
April 1990	-	Space planning/interior design begins.
September 1990	-	Base building construction begins.
September 1991	-	Tenant buildout begins.
Apr-Sept. 1992	-	Phased move.
October 1992	-	Occupancy complete.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Activity	FY 1989 Actual	FY 1990 Current Plan	FY 1991 Request	Difference FY 91/90
Architectural and engineering services	$0.00	$0.00	$0.40	$0.40
Other consulting services	0.00	0.00	0.60	0.60
Special purpose furniture and equipment	0.00	0.00	1.00	1.00
Above-standard alterations	0.00	0.00	1.50	1.50
Telecommunications start-up	0.00	0.00	2.00	2.00
Total	$0.00	$0.00	$5.50	$5.50

The request of $5.5 million for 1991 will provide funding for Architectural and Engineering services, special purpose furniture and equipment, consulting services, above standard alterations and telecommunications start-up. Subsequent budget submissions will contain requests to fund other relocation support activities. An acceleration of the construction and buildout phases in FY 1991 may require funding for activities in FY 1991 that are currently scheduled to occur in FY 1992.

The total cost of the relocation through 1992 is estimated at $17 million and includes the following services and support efforts.

A&E (Design) Services - Architectural and Engineering Services required to design all interior spaces in new facility.

Consulting Services - These services include telecommunications system design, conference and training facility design, project planning and management services during construction phase, and move planning and coordination.

Special Purpose Furniture and Equipment - This category includes specialized furniture and equipment for conference and training center (projection, audio/visual, graphics), centralized file storage, library, lounge, mail, proposal processing, printing, and composition.

Above Standard Alterations - These alterations include demountable floor-to-ceiling panel systems and sound masking throughout open spaces. The panel system will facilitate the reconfiguration of space and allow maximum utilization of space throughout the life of the building.

Telecommunication Start-up - All wire, conduit, connectors, zone boxes, racks and components in closets, digital telephone equipment at workstations, and labor to pull, connect and test needed to bring telecommunication service (voice/data/video) from wire closets to all workstations.

Data Center Relocation - This category includes all new equipment, wiring, and relocation costs associated with the move of the mainframe to the new building. This request does not cover the cost of any new mainframe components or peripheral devices but may include motor generators, cooling equipment, communications infrastructure and other support equipment.

cost of any new mainframe components or peripheral devices but may include motor generators, cooling equipment, communications infrastructure and other support equipment.

ADP Distributed Systems Relocation - This category includes all new equipment, wiring and relocation costs associated with the move of all distributed ADP systems (i.e., PC workstations) to the new building. This budget does not cover the cost of any new PC components or peripheral devices but may include communications infrastructure and other support equipment.

Dual Operations - This category includes telecommunications service (including data communications links from all workstations to mainframe and backbone network throughout phased move), mail and delivery, security, shuttle, and other automation and administrative support services required to support both the existing and new facilities during currently scheduled 6-month phased move.

Office Furniture - Furniture and files to outfit all office and conference/training spaces in the new building.

Moving Services - Labor and transportation services needed for physical move from existing locations to new facility.

U. S. ANTARCTIC PROGRAM $175,000,000

SUMMARY OF REQUEST

The FY 1991 Budget Request for the U.S. Antarctic Program (USAP) is $175.00 million, an increase of $23.32 million, or 15.4 percent, over the FY 1990 Current Plan of $151.68 million, which is the total of the two appropriations accounts for USAP.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
U.S. Antarctic Research Program	$15.57	$17.50	$17.02	$19.00
Operations Support	88.50	102.20	99.37	110.00
Major Construction and Procurement	27.00	36.30	35.29	46.00
Total, Activity	$131.07	$156.00	$151.68	$175.00
Total by FY 1990 Appropriation				
Antarctic Logistical Support	N/A	$82.00	$79.73	$75.00
Antarctic Program Activities	N/A	74.00	71.95	100.00

NSF ROLE

The U.S. Antarctic Program supports national goals in the Antarctic: to maintain the Antarctic Treaty, to ensure that the continent continues to be used only for peaceful purposes, to foster cooperative research contributing to the solution of regional and world-wide problems, to protect the environment, and to ensure the equitable and wise use of living and nonliving resources.

A major, multi-year Safety, Environment, and Health initiative, which began in FY 1990, will be expanded significantly in FY 1991. A comprehensive approach to improvements in these areas is necessary to deal with problems that have accumulated and to meet higher standards. The goals of the initiative are:

- Safety: to achieve year-round operations in the Antarctic with modern technology and acceptable risk;
- Environment: to clean up the debris of past operations and to bring present operations into accord with current regulations;
- Health: to improve medical facilities and to provide field parties with safety experts who have medical training.

This initiative responds to the recommendations in *Safety in Antarctica*, the report of a special antarctic safety panel appointed by NSF. While the U.S. Antarctic Program has begun to deal with these matters, a number of serious problems continue to exist, including waste disposal, environmental monitoring, communications, and emergency facilities.

The antarctic area is important because of its major influence on world weather, climate, and ocean circulation, and its unique environment for international cooperation. NSF plays a major role by funding both the basic scientific research performed in the Antarctic and the necessary logistic support, and by managing the total program. This program supports research on topics that contribute directly to the NSF Global Geosciences Program, such as climate change, ocean circulation, sea/air/ice interaction, and formation and mixing of nutrient-rich bottom water.

A significant goal has been to understand the seasonal decrease in stratospheric ozone and resultant biological effects. Efforts have included investigations of the causes of the decrease; the effects of the resulting increased ultraviolet (UV) radiation on biological systems; operation of UV monitoring equipment at the South Pole, McMurdo, and Palmer Stations and at Ushuaia, Argentina; and a multidisciplinary, international research program using the UV data collected.

The United States also conducts mapping and charting, weather observations, sea-ice analysis, and forecasting activities. Representatives of federal agencies, under guidance of the Department of State, conduct periodic inspections of non-U.S. antarctic installations under Article VII of the Antarctic Treaty. Many projects are performed by other federal agencies, with funding, management, facilities, and operational support provided by NSF. Other agencies may also fund and undertake short-term scientific programs subject to special review.

The National Security Council Policy Coordinating Committee on International Oceans, Environment and Science Affairs, chaired by the Department of State, is responsible for providing policy guidance. The Polar Research Board of the National Academy of Sciences provides continuing advice on scientific opportunities and priorities.

FY 1990 funds for the U.S. Antarctic Program were requested in a single account, but were appropriated in two accounts: Antarctic Logistical Support and Antarctic Program Activities. These two accounts for USAP have been reconstructed in the FY 1990 Current Plan and the FY 1991 Budget Request. A crosswalk for these accounts is shown below.

CROSSWALK FOR ANTARCTIC APPROPRIATIONS FY 1990 - FY 1991
(Millions of Dollars)

Subactivity	FY 1990 Current Plan			FY1991 Request		
	Program Activities	Logistical Support	Total	Program Activities	Logistical Support	Total
U.S. Antarctic Research Program . .	$17.02	$0.00	$17.02	$19.00	$0.00	$19.00
Operations Support	32.47	66.90	99.37	47.00	63.00	110.00
Major Construction and Procurement	22.46	12.83	35.29	34.00	12.00	46.00
Total, Activity	$71.95	$79.73	$151.68	$100.00	$75.00	$175.00

Logistical Support in the FY 1990 Current Plan includes funding for some activities related to the Safety, Environment, and Health initiative, as well as funds used to reimburse the Department of Defense for logistics support. The breakout of Logistical Support for the FY 1991 Request includes only those funds for reimbursement to the Department of Defense.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
U.S. Antarctic Research Program	$15.57	$17.50	$17.02	$-0.48	-2.8%
Operations Support	88.50	102.20	99.37	-2.83	-2.8
Major Construction and Procurement	27.00	36.30	35.29	-1.01	-2.8
Total, Activity	$131.07	$156.00	$151.68	$-4.32	-2.8%
Total by FY 1990 Appropriation					
Antarctic Logistical Suport	N/A	$82.00	$79.73	-$2.27	-2.8%
Antarctic Program Activities	N/A	74.00	71.95	-2.05	-2.8%

The FY 1990 Current Plan is $151.68 million, a decrease of $4.32 million, or 2.8 percent, from the FY 1990 Budget Request of $156.00 million, but an increase of $20.61 million, or 15.7 percent, over FY 1989. The decrease results from the Congressionally mandated reductions, and was distributed proportionately across the requested increments in each Subactivity.

Initial funding for the Safety, Environment, and Health initiative in FY 1990 is being used for:

- clean-up of the former dump at Winter Quarters Bay and other activities to remedy adverse environmental impacts of past activities;
- studies in major problem areas, including the development of an improved system for disposal of solid waste;
- monitoring of drinking and waste water;
- utilities improvements to increase fire suppression capabilities and treatment of wastewater;
- improved air-traffic control systems including navigation aids and communications.

Availability of funds in the Logistic Support appropriation is delayed until September 30, 1990, per Congressional direction, with serious impacts on program operations. For example, upgrades of LC-130 aircraft are being deferred due to the availability of funding. Technicalities may slow progress for the Safety, Environment, and Health initiative, which was included in the Antarctic Logistics Support account.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
U.S. Antarctic Research Program	$17.02	$19.00	$1.98	11.7%
Operations Support	99.37	110.00	10.63	10.7
Major Construction and Procurement	35.29	46.00	10.71	30.3
Total, Activity	$151.68	$175.00	$23.32	15.4%

The FY 1991 Request is $175.00 million, an increase of $23.32 million, or 15.4 percent, above the FY 1990 Current Plan.

The increase includes a $17.00 million increment for the multi-year Safety, Environment, and Health (SEH) initiative, for a total of $25.30 million. These funds will provide:

- $5.70 million for environmental activities, including: outfalls for wastewater that has already received primary treatment; design and initial procurement of appropriate incinerators and measures to expand cleanup necessitated by past activities; and minimization of future waste production and other potential environmental hazards such as oil spills.
- $11.30 million for safety and health activities. About half of this increment supports facilities improvements, particularly at South Pole Station, to meet minimum standards and to design the future South Pole Station. The remainder supports upgrades of field party operations and search and rescue communications, as well as air traffic control and precision landing systems that provide increased safety and move toward a year-round airplane landing capability.

Support for the U.S. Antarctic Research Program will increase by $1.98 million, with an emphasis on geophysics, long-term ecological research, and ocean sciences. Operations Support will increase by a total of $10.63 million. This includes $3.72 million for science support, particularly for geophysics research, $1.70 million for SEH efforts, and $5.21 million for increased cost of logistics. The $10.71 million increase for Major Construction and Procurement is the result of a $15.30 million increase for SEH offset by decreases in construction costs for dorms and the science laboratory at McMurdo Station.

U.S. ANTARCTIC RESEARCH PROGRAM $19,000,000

SUMMARY OF REQUEST

The FY 1991 Budget Request for the U.S. Antarctic Research Program is $19.00 million, an increase of $1.98 million or 11.6 percent, over the FY 1990 Current Plan of $17.02 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
U.S. Antarctic Research Program	$15.57	$17.50	$17.02	$19.00

SCIENTIFIC OVERVIEW

The major objective of the U.S. Antarctic Research Program Subactivity is to provide for study of the physical and biological environments of Antarctica. Studies focus on the solid earth, the overlying and surrounding ice, the oceans, the atmosphere, and the terrestrial and marine biota. In atmospheric sciences, Antarctica represents a unique natural laboratory for investigating the upper atmosphere, high latitude and cold climate phenomena, weather, and solar dynamics. Ocean studies address the dynamics, paleontology, and ecology of the seas surrounding the continent. Earth sciences studies address geology, geophysics, glaciology, and plate tectonics. These research efforts seek to place antarctic environmental processes in a global context.

The scientific leadership gained through these investigations ensures a strong U.S. position in the Antarctic Treaty system under which the future of the region will be decided. Topics of concern include protection and conservation of the antarctic environment and wise management of the living and non-living resources.

The Subactivity also funds curatorial centers for storing and distributing ice cores and ocean sediment cores, and for sorting and distributing natural history specimens; publications that disseminate antarctic research information; scientific advice through support of the Polar Research Board; and mapping by the U.S. Geological Survey. During the average 120-day field season, the subactivity supports about 300 scientists involved in some 80 research projects. Remote sensing techniques using satellites, aircraft, balloons, and unmanned stations are also employed in the conduct of research. Research projects supported entirely by other agencies or undertaken jointly with NSF-supported investigators are often included, and cooperative research programs with scientists of other nations are commonplace.

An ongoing project of global significance concerns the seasonal depletion of ozone over the Antarctic. Stratospheric ozone is a critical factor in the environment because it shields the earth from hazardous ultraviolet radiation from the sun. Also of potential global significance are complex changes in the West Antarctic Ice Sheet that are being studied by glaciologists. The instability of this ice sheet appears greater than previously expected. Its collapse would be of great societal concern because world-wide sea level could rise by 20 feet over a 200-year period.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
U.S. Antarctic Research Program	$15.57	$17.50	$17.02	$-0.48	-2.8%

The FY 1990 Current Plan is $17.02 million, a decrease of $0.48 million, or 2.8 percent, from the FY 1990 request of $17.50 million, but an increase of $1.45 million, or 9.3 percent, over FY 1989. The decrease is the result of the Congressionally mandated reductions.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
U.S. Antarctic Research Program	$17.02	$19.00	$1.98	11.7%

The FY 1991 Budget Request is $19.00 million, an increase of $1.98 million, or 11.7 percent, above the FY 1989 Current Plan level of $17.02 million.

Research across the disciplines applicable to Antarctica will be continued, with some changes in emphasis. The $1.98 million increase will provide for an additional long-term ecological research project, progress on a large-scale geophysics program, and expansion of ocean research. Specific research areas that will be emphasized in FY 1991 include:

- biological effects of increased ultraviolet radiation due to ozone depletion, particularly on the marine food web, and of the BAHIA PARAISO oil spill at Palmer Station;
- dynamics of the West Antarctic Ice Sheet and clarification and extension of the climate record gained from ice drilling and coring;
- the formation and flow of cold, nutrient-rich bottom water, which has implications for marine ecosystems, world-wide weather, climate and other aspects of the Antarctic's role in global environmental systems;
- long-term ecological research;

- research in astronomy and astrophysics that capitalizes on the unique location of the South Pole Station; and
- a new geophysical study of the geological history of the Antarctic.

In addition to the $19.00 million budgeted in FY 1991 for research under the Research Program, the Operations Support Subactivity provides funding for direct support necessary for the conduct of the research.

OPERATIONS SUPPORT *$110,000,000*

SUMMARY OF REQUEST

The FY 1991 Budget Request for Operations Support is $110.00 million, an increase of $10.63 million, or 10.7 percent, over the FY 1990 Current Plan of $99.37 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science Support	$19.30	$26.00	$24.28	$28.00
Operations and Maintenance	69.20	76.20	75.09	82.00
Total, Subactivity	$88.50	$102.20	$99.37	$110.00

OVERVIEW

This Subactivity funds the science support and operations required for the conduct of research in the most cost effective manner consistent with safety, reliability, and the maintenance of an effective U.S. presence in Antarctica.

All forms of support and services needed to conduct research in Antarctica must be imported. The provision of such support and services is grouped, for central management purposes, in the Operations Support Subactivity.

Science Support includes those costs which directly support research and which would not be incurred if the United States were merely to maintain a presence in Antarctica. This program element funds operation of research ships, notably R/V POLAR DUKE, and the planned acquisition of a research ship with icebreaking capability. Also included are costs of transportation to and from Antarctica, special cold weather clothing and equipment, aircraft support for research programs, field camp support, and research equipment.

Operations and Maintenance provides the continuing services that underpin the U.S. presence in Antarctica and make the science program possible. These services are provided on a reimbursable basis primarily by the Department of Defense and a civilian contractor.

The U.S. Naval Support Force Antarctica (NSFA) provides the primary DOD logistic support for the U.S. Antarctic Program. This support includes operation of McMurdo Station (the main staging point for most U.S. activities on the continent) and the year-round operation of Antarctic Development Squadron Six (VXE-6), which provides U.S. air support in Antarctica with seven NSF-owned ski-equipped LC-130 aircraft and six Navy UH-1N helicopters. Additionally, the NSFA is responsible for surface and air transport of cargo and personnel between New Zealand

and Antarctica. The NSFA arranges for the charter of special mission Air Force C-141s and the ships that deliver most of the cargo and petroleum to Antarctica, and has operational control of the U.S. Coast Guard icebreaker that breaks and maintains the channel through the sea ice of McMurdo Sound each year. The Naval Support Force also maintains a communications and staging base detachment in Christchurch, New Zealand, on a year-round basis.

A new civilian contractor, Antarctic Support Associates, a joint venture of Holmes and Narver Services, Inc. and EG&G Inc., has been selected for a contract period beginning April 1, 1990. The contractor is responsible for the operation and maintenance of two research stations--South Pole and Palmer--and for maintenance at McMurdo. The contractor also carries out major construction in Antarctica, and provides some of the logistic and specialized support, such as operation and maintenance of the R/V POLAR DUKE.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY1990 Current Plan	Change	
				Amount	Percent
Science Support	$19.30	$26.00	$24.28	$-1.72	-6.6%
Operations and Maintenance	69.20	76.20	75.09	-1.11	-1.5
Total, Subactivity	$88.50	$102.20	$99.37	$-2.83	-2.8%

The FY 1990 Current Plan is $99.37 million, a decrease of $2.83 million, or 2.8 percent, from the FY 1990 Budget Request of $102.20 million, but an increase of $10.87 million, or 12.3 percent, over FY 1989. The reduction is this Subactivity's share of the Congressionally mandated reductions.

The Science Support program element will be reduced by $1.72 million, of which $0.72 million is taken from funds planned for acquisition of a research vessel with icebreaking capability, and $1.00 million from contractor support of research.

The Operations and Maintenance program element is reduced by $1.11 million. This decrease is the net of a $1.70 million reduction in the Safety, Environment, and Health initiative partially offset by a $0.59 million increase to meet operational requirements.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Science Support	$24.28	$28.00	$3.72	15.3%
Operations and Maintenance	75.09	82.00	6.91	9.2
Total, Subactivity	$99.37	$110.00	$10.63	10.7%

The FY 1991 Budget Request is $110.00 million, an increase of $10.63 million, or 10.7 percent above the FY 1990 Current Plan level of $99.37 million. Of the increase, Science Support is allocated $3.72 million for increased ship, aircraft and contractor support. The remaining $6.91 million is planned for Safety, Environment, and Health efforts, increased aircraft maintenance, and other operating costs.

SCIENCE SUPPORT

This program element increases by $3.72 million, or 15.3 percent, from $24.28 million to $28.00 million, and will fund the following:

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
Contractor Equipment and Operations	$10.78	$11.80
R/V POLAR DUKE	4.60	4.80
Research Ship (Icebreaking)	3.80	4.50
UNOLS Vessel Charter	–	1.10
Aircraft Operations	3.00	3.60
Transportation of Scientific Personnel and Cargo	2.10	2.20
Total	$24.28	$28.00

Contractor Equipment and Operations includes operation of South Pole and Palmer Stations on a year-round basis, and major field camps at remote locations on a periodic basis. The contractor supplies and operates the Eklund Biological Laboratory and the Berg Field Center at McMurdo Station. The contractor also leases Twin Otter aircraft (accounting for most of the aircraft operations increase) and the ice-strengthened research vessel POLAR DUKE. This vessel operates in the summer in the Antarctic Peninsula and elsewhere in the southern seas as required.

A second research vessel is being obtained to provide a research platform for operations in ice too heavy for R/V POLAR DUKE. This ship will be used for year-round antarctic research. Funds are provided for a short-term charter of a specialized research vessel of the University National Oceanographic Laboratory System (UNOLS) for antarctic geophysics. Funds for aircraft operations for science projects using the LC-130s and UH-1Ns, and for other aircraft needed for specialized science support, are included in this program element.

OPERATIONS AND MAINTENANCE

The Operations and Maintenance program element increases by $6.91 million, or 9.2 percent, from $75.09 million to $82.00 million. Of this increase, $1.70 million will be used for the Safety, Environment, and Health initiative for additional activities, such as upgrades of medical facilities and provision of field safety experts as members of science field parties. The balance of the increment, $5.21 million, will be applied to the increased costs of the operations shown below.

(Millions of Dollars)

	FY 1990 Estimate	FY1991 Estimate
Personnel	$30.80	$31.30
Air Operations	15.88	17.00
Surface Transportation	2.60	2.70
USCG Icebreaker Costs	2.60	2.70
Antarctic Continent Operations	21.10	25.80
US and New Zealand Operations	2.11	2.50
Total	$75.09	$82.00

Personnel is the largest cost element. It pays for the nearly 800 military personnel of the Naval Support Force Antarctica and Antarctic Development Squadron Six (VXE-6), as well as for civilians working under contract.

Air Operations includes the cost of VXE-6 flight activity and standard maintenance of the aircraft. Also included are the costs of additional airlift chartered from the U.S. Air Force and of personnel transportation in connection with the Antarctic Program.

Surface Transportation costs include the charter of Military Sealift Command cargo and fuel ships for the resupply of McMurdo Station, which is also the resupply base for operations in the interior of the continent.

U.S. Coast Guard icebreaker costs are for the McMurdo channel break-in and escort of the supply ships.

The Antarctic Continent Operations are those associated with maintaining the base at McMurdo and adjacent air fields, support of South Pole and Palmer Stations and field camps, and the Safety, Environment, and Health initiative.

MAJOR CONSTRUCTION AND PROCUREMENT $46,000,000

SUMMARY OF REQUEST

The FY 1991 Budget Request for the Major Construction and Procurement Subactivity is $46.00 million, an increase of $10.71 million, or 30.3 percent, over the FY 1990 Current Plan of $35.29 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Major Construction and Procurement	$27.00	$36.30	$35.29	$46.00

OVERVIEW

Major Construction and Procurement provides for the design, procurement, and construction of replacement facilities and for equipment needed for operations and science support. It funds the procurement of electronics, vehicles, and construction equipment and major repair and modifications to aircraft. These activities are carried out by a civilian contractor and the Naval Support Force.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Major Construction and Procurement	$27.00	$36.30	$35.29	$-1.01	-2.8%

The FY 1990 Current Plan is $35.29 million, a decrease of $1.01 million, or 2.8 percent, from the FY 1990 Budget Request of $36.30 million, but an increase of $8.29 million, or 30.7 percent, over FY 1989. The decrease results from unspecified Congressional reductions.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Major Construction and Procurement	$35.29	$46.00	$10.71	30.3%

The FY 1991 Request is $46.00 million, an increase of $10.71 million over the FY 1990 Current Plan of $35.30 million.

Support for projects related to the Safety, Environment, and Health (SEH) initiative increases by $15.30 million. This increase is partially offset by $4.59 million in decreases in other components of the Subactivity.

The increases for the SEH initiative include the following for Construction and Procurement:

- fuel storage improvements,
- South Pole Station design,
- McMurdo Station incinerator,
- hazardous waste storage facility,
- Palmer Station rehabilitation,
- navigational aids for aircraft and field parties, and
- improved ground transportation.

These expenses are steps toward implementation of significant improvements in safety and environmental protection.

Construction costs represent an ongoing effort to restore or replace obsolete facilities at McMurdo, Palmer and South Pole Stations. Some projects, such as the McMurdo dormitories, are planned for completion in FY 1991. Construction of a science laboratory at McMurdo Station to replace present temporary and outmoded facilities will continue. Foundations for the laboratory were laid in FY 1988, and completion of the first wing of the laboratory is planned for FY 1991; procurement of structural materials and equipment for the second and third wings will be nearly complete by FY 1991.

SCIENCE AND ENGINEERING EDUCATION $251,000,000

SUMMARY OF REQUEST

The FY 1991 Request for the Science and Engineering Education (SEE) Activity is $251.00 million, an increase of $46.73 million, or 22.9 percent, over the FY 1990 Current Plan of $204.27 million.

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Teacher Preparation and Enhancement	$63.66	$68.50	$81.00	$89.60
Materials Development, Research, and Informal Science Education	43.99	49.00	48.00	61.50
Undergraduate Science, Engineering, and Mathematics Education	28.00	30.00	34.00	50.00
Research Career Development	30.98	38.00	36.90	44.90
Studies and Program Assessment	4.50	4.50	4.37	5.00
Total, Activity	$171.13	$190.00	204.27	$251.00

NSF ROLE

The responsibility of the Science and Engineering Education (SEE) Activity is to define and fund programs and projects that support the educational aspects of the Foundation's mission. SEE also plays a major role in developing human resources for science and engineering. The magnitude of the educational effort in the United States and the long lead times needed for new programs, materials, and methods require a continuing and significant involvement in this area. Sustaining this level of commitment, visibility, and continuity is responsive to the national concern with science, mathematics, and engineering education and will draw the best, most creative people into the process.

SEE fulfills this responsibility by conducting leadership activities that inform and stimulate other sectors, and by supporting original work and other merit-based, high-leverage activities that serve as prototypes and models of excellence for the Nation. A major objective is to encourage appropriate cooperation among academic scientists, engineers, educators and the private sector for intellectual partnerships as well as for leveraging funds.

The National Science Foundation is active at all levels of education - precollege, undergraduate, graduate, and postgraduate. SEE serves as the focal point for education at NSF. In this role SEE manages the programs for which it has sole budgetary responsibility, and serves in a coordinating and facilitating capacity for the other administrative units throughout the Foundation.

The role of SEE is to help ensure that:

- a high-quality precollege education in science and mathematics is available to enable those who are interested and talented to pursue technical careers, especially in science and engineering, as well as to provide a base for understanding by all citizens;
- those who select scientific and engineering careers have available the best possible professional education in their disciplines. While other NSF programs provide apprenticeship training for the next generation of scientists and engineers through research support, SEE's efforts (in addition to graduate and postdoctoral fellowships) concentrate on the educational structure leading to this stage; that is, on the teachers, students, laboratory, and classroom resources that remain important through undergraduate and graduate studies;
- opportunities are available at the college level for interested nonspecialists to broaden their science, mathematics, and technical perspective and understanding to familiarize them with the principles, practices, techniques, and limits of science;
- informal science education programs are available to maintain public awareness of and interest in scientific and technological developments affecting their lives; and
- the educational pipelines leading to careers in science, engineering and mathematics yield sufficient numbers of well-educated individuals to meet the needs of the U.S. technical workforce. Increasing the participation in such careers of minorities, women, and the disabled receives special attention at all educational levels.

Several SEE programs have specific requirements for cost sharing and other forms of funds leveraging. Data for FY 1989 demonstrate that precollege teacher enhancement and teacher preparation projects generate non-NSF funds equal to one-half of NSF funds invested, while projects in instructional materials development and informal science education generate external funding equal to three times the amount of the NSF awards. At the undergraduate level, there is a 1:1 matching requirement for equipment purchases.

SEE coordinates its activities closely with other relevant areas of NSF and with other agencies, e.g. NASA, Department of Energy and the Department of Education (DoEd). Such coordination is intended to promote maximum use of expertise in the agencies, to minimize program overlap, and to optimize the use of limited Federal resources. Within the Foundation, the undergraduate instrumentation support is an example of an integrated management effort led by the SEE Activity and involving all of the Research Directorates. Externally, NSF and DoEd have collaborated in supporting a number of projects, including the International Study of Mathematics, the International Science Study, International Comparison of 13-year-olds, and a study of state-based science and math indicators at the precollege level. NSF, NASA, and the Department of Energy have jointly co-funded the National Academy of Science's "Mathematical Sciences Education Board".

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Subactivity	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Teacher Preparation and Enhancement	$63.66	$68.50	$81.00	$12.50	18.2%
Materials Development, Research, and Informal Science Education	43.99	49.00	48.00	-1.00	-2.0
Undergraduate Science, Engineering, and Mathematics Education	28.00	30.00	34.00	4.00	13.3
Research Career Development	30.98	38.00	36.90	-1.10	-2.9
Studies and Program Assessment	4.50	4.50	4.37	-0.13	-2.9
Total, Activity	$171.13	$190.00	$204.27	$14.27	7.5%

The FY 1990 Current Plan is $14.27 million more than the FY 1990 Request of $190.0 million, and $33.14 more than FY 1989, a 19.4 percent increase. The distribution of the increase, as specified by Congress, is to the pre-college Teacher Preparation and Enhancement Subactivity and to the Career Access Program of the Undergraduate Science, Engineering, and Mathematics Education Subactivity. All Subactivities are then reduced by the Gramm-Rudman-Hollings sequestration and other mandated across-the-board reductions to arrive at the Current Plan.

Across the Activity in FY 1990:

- precollege programs total $140.37 million ($21.22 million more than FY 1989, a 17.8 percent increase);
- undergraduate programs total $34.0 million ($6.00 million more than FY 1989, a 21.4 percent increase);
- graduate programs total $29.9 million ($5.92 million more than FY 1989, a 24.7 percent increase).

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Subactivity	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Teacher Preparation and Enhancement	$81.00	$89.60	$8.60	10.6%
Materials Development, Research, and Informal Science Education	48.00	61.50	13.50	28.1
Undergraduate Science, Engineering, and Mathematics Education	34.00	50.00	16.00	47.1
Research Career Development	36.90	44.90	8.00	21.7
Studies and Program Assessment	4.37	5.00	0.63	14.4
Total, Activity	$204.27	$251.00	$46.73	22.9%

The Teacher Preparation and Enhancement Subactivity will continue to focus on improvement of precollege science and mathematics education through effective preservice and in-service teacher training. In FY 1991, emphasis will be placed on the Statewide Initiatives to forge strong Federal-State partnerships to restructure pre-college education throughout the Nation. This effort will assist states in meeting the national education goals that are being developed as a result of the September, 1989 Education Summit.

The Materials Development, Research, and Informal Science Education Subactivity will continue to focus on the need for a consistent pattern of elementary and secondary school science and mathematics instruction. A major effort will be continued in FY 1991 to develop improved instructional materials for science in the secondary schools. Informal science activities and research about the teaching and learning process will also be emphasized. Programs to develop and demonstrate the use of modern technology in addressing educational problems will continue.

Programs in the Undergraduate Science, Engineering, and Mathematics Education Subactivity will increase substantially in FY 1991. In addition to the continued SEE emphasis on strengthening college instrumentation and laboratories (College Science Instrumentation Program), the effort will be expanded by assuming responsibility for all types of institutions. Comprehensive regional centers for minorities and other model collegiate programs to stimulate the participation of women, minority, and disabled students in curricula leading to science careers will be substantially increased to support approximately 15 centers throughout the Nation by FY 1991. Efforts to enhance the currency of undergraduate faculty and to improve the undergraduate curricula will also increase significantly.

The Research Career Development Subactivity will continue its current efforts. The number of new three-year graduate fellowships will be increased to 1100, completing the planned doubling of the program from its level of 560 new fellowships in FY 1987. This number includes the continuation of a specially-focused "Women in Engineering" offering to attract more women into the Nation's engineering faculty. The funding will also permit an expansion of the Young Scholars Program for talented high school and middle school students who may be candidates for careers in mathematics, engineering, and the sciences. The amount requested for this Subactivity in FY 1991 includes an increase in the fellowship stipend to $13,500 per year, and reflects the third step in an administrative adjustment in the funding schedule for the Graduate Fellowships and Minority Graduate Fellowships Programs.

The Studies and Program Assessment Subactivity will continue its studies of national and international trends relevant to science education, the collection and analysis of data on science and engineering education issues, and the support of related policy studies. Efforts to assess the results of NSF education programming will be expanded.

SUMMARY BY EDUCATIONAL LEVEL

The allocation to programming at the various educational levels of FY 1990 appropriations and the funds requested for FY 1991 are shown in the following table.

(Millions of Dollars)

Educational Level	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Pre-college	$140.37	$165.10	$24.73	17.6%
Undergraduate	34.00	50.00	16.00	47.1
Graduate	29.90	35.90	6.00	20.1
Total, Activity	$204.27	$251.00	$46.73	22.9%

CROSSWALK: SUBACTIVITY to EDUCATIONAL LEVEL (FY 1991)

The allocations to programming by each Subactivity at the various educational levels of funds requested for FY 1991 are shown in the following table.

(Millions of Dollars)

Subactivity	Pre-college	Undergraduate	Graduate
Teacher Preparation and Enhancement	$89.60	$0	$0
Materials Development, Research and Informal Science Eeducation	61.50	0	0
Undergraduate Science, Engineering, and Mathematics Education	0	50.00	0
Research Career Development.	9.00*	0	35.90
Studies and Program Assessment	5.00	0	0
Total, SEE	$165.10	$50.00	$35.90

* The Young Scholars Program ($9.00 million) is the pre-college element of the Research Career Development Subactivity.

TEACHER PREPARATION AND ENHANCEMENT $89,600,000

SUMMARY OF REQUEST

The FY 1991 Request for the Teacher Preparation and Enhancement (TPE) Subactivity is $89.6 million, an increase of $8.6 million, or 10.6 percent, over the FY 1990 Current Plan of $81.0 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Science & Mathematics Education Networks	$9.00	$10.00	$16.00	$23.00
Teacher Enhancement	45.13	46.00	53.10	54.20
Teacher Preparation	7.72	10.00	9.00	9.50
Presidential Awards for Excellence in Science & Mathematics Teaching	1.81	2.50	2.90	2.90
Total, Subactivity	$63.66	$68.50	$81.00	$89.60

EDUCATIONAL OVERVIEW

Since teachers are the core of the educational system, the improvement of science and mathematics education places strong emphasis on programs for those who will teach these subjects. Accordingly, the Teacher Preparation and Enhancement Subactivity promotes and supports activities to improve (1) the preparation of those seeking to become teachers, (2) continued professional development of active teachers, (3) development of support networks for teachers, and (4) recognition of outstanding teachers.

TPE programs recognize the broad scope of science and mathematics education at all grade levels. For example, appreciation of the crucial role that the quality of science exposure during elementary school plays in establishing lifelong attitudes has led to greatly increased emphasis at that level. The programs must serve students with widely varied backgrounds; particularly important are improved ways to reach students from groups underrepresented in scientific and mathematical activities -- women, minorities, and the disabled.

Science and mathematics courses must meet the post-school needs of all students: those who will become professional scientists and engineers; the equally important group who will perform the non-college-based technical jobs crucial to our national economy; and all of us who as citizens must make the final decisions on the science-based issues facing society. This commitment to breadth is built into all segments of this Subactivity.

In teacher preparation, one emphasis is on programs to attract students into careers in K-12 science and mathematics teaching. An important goal is to increase the number of minority students electing such careers, because of the important role of the teacher as role model. Programs underway or being developed involve outreach at the precollege level to interest minority students in this career path and support of appropriate college and university teacher education programs.

Another teacher preparation goal is to promote programs which prepare middle and high school science teachers to teach effectively more than one science discipline. As yet, few colleges have teacher preparation programs oriented toward a multidisciplinary curriculum.

In teacher enhancement, one emphasis is accelerating the application of new teaching technologies. Electronic and other new devices are important tools for the teacher, but effective utilization requires understanding by the teacher of the potential of the system as well as careful planning for its integration into teaching patterns.

Another teacher enhancement emphasis is on improving the effectiveness of science and mathematics teaching in schools with high minority populations. The nation's demography shows that these populations will have to yield a steadily increasing fraction of the technical work force at both the professional and artisan levels. The past underrepresentation of these groups in technology-based positions means minority students often have lacked early exposure to science- and mathematics-based topics. Teaching strategies that develop interest and build confidence in dealing with such topics are therefore particularly important.

Teacher support networks are valuable because science and mathematics teachers lack opportunities for interaction with practicing scientists, mathematicians, and even with other teachers in the same fields. Since Presidential Science and Mathematics Awardees are an important pool of persons with demonstrated teaching excellence, networks are being developed to make their know-how and enthusiasm available to other teachers. Another emphasis is on substantial expansion of the programming designed specifically to involve private sector scientists, engineers, and mathematicians in partnerships with local teachers and schools.

Past evidence indicates that NSF leadership and support in working with science and mathematics teachers can have a major national impact. The expanding teacher preparation and enhancement programs are meeting widely recognized national needs for improvements in science and mathematics education.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Science and Mathematics Education Networks	$9.00	$10.00	$16.00	$6.00	60.0%
Teacher Enhancement	45.13	46.00	53.10	7.10	15.4
Teacher Preparation	7.72	10.00	9.00	-1.00	-10.0
Presidential Awards for Excellence in Science & Mathematics Teaching	1.81	2.50	2.90	0.40	16.0
Total, Subactivity	$63.66	$68.50	$81.00	$12.50	18.2%

The FY 1990 Current Plan is $12.5 million more than the FY 1990 Request of $68.5 million, and $17.34 million more than FY 1989, a 27.2 percent increase. The 18.2 percent increase over the FY 1990 Request will be used primarily to support additional teacher enhancement efforts, particularly with projects to support in-service efforts that increase leader-teacher capabilities to serve their colleagues, and in-service projects that focus on helping teachers in a number of urban areas serving large numbers of minority students.

The increased funding for the Networks Program will permit the initiation of programs to assist states in their efforts to address the systemic nature of problems facing science and mathematics with comprehensive responses, as well as to assist nation-wide reform initiatives currently under way. These resources will be used in the implementation of the Statewide Initiatives effort to take advantage of the unique opportunity now available for Federal/State partnerships.

The $9.00 million allocated for Teacher Preparation, an increase of 16.6 percent over FY 1989, provides expanded support for innovative projects to address the shortfalls in the mathematics and science content of teacher education.

The Presidential Awards for Excellence in Science and Mathematics Teaching will be doubled in FY 1990. In addition to the junior high / high school teachers currently eligible for these prestigious awards, elementary teachers will now be recognized through a comparable, but separate, set of annual awards. A total of 216 outstanding teachers will receive Presidential Awards in FY 1990.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Science & Mathematics Education Networks	$16.00	$23.00	$7.00	43.8%
Teacher Enhancement	53.10	54.20	1.10	2.1
Teacher Preparation	9.00	9.50	0.50	5.6
Presidential Awards for Excellence in Science & Mathematics Teaching	2.90	2.90	0.00	0.0
Total, Subactivity	$81.00	$89.60	$8.60	10.6%

The FY 1991 Budget Request is $8.6 million more than the FY 1990 Current Plan of $81.0 million.

The 10.6 percent increment will support a number of increased efforts:

- Significant expansion of the Statewide Initiatives, under the Science and Mathematics Education Networks Program;
- Expansion of the Science and Mathematics Networks Program to include comprehensive reform efforts in urban areas;
- Additional efforts through the in-service Teacher Enhancement Program to focus on leader-teacher projects.

MATERIALS DEVELOPMENT, RESEARCH, AND INFORMAL SCIENCE EDUCATION $61,500,000

SUMMARY OF REQUEST

The FY 1991 Request for the Materials Development, Research and Informal Science Education (MDRISE) Subactivity is $61.5 million, an increase of $13.5 million, or 28.1 percent, over the FY 1990 Current Plan of $48.0 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Instructional Materials Development	$18.50	$21.50	$21.20	$31.00
Research in Teaching and Learning	4.50	5.00	4.80	5.00
Informal Science Education	15.00	16.00	15.70	19.00
Applications of Advanced Technology	5.99	6.50	6.30	6.50
Total, Subactivity	$43.99	$49.00	$48.00	$61.50

EDUCATIONAL OVERVIEW

This Subactivity seeks to increase the quality of science, mathematics, and technology education at all precollege levels by improving the instructional materials and teaching methods used in the classroom and by enriching the environment for informal learning outside the school. Efforts are focused particularly on reinforcing the positive attitudes toward science that are typical of beginning students and on providing rich science experiences that encourage continuing participation in scientific studies.

Most students enter school with little science background but great enthusiasm for experimenting and exploring. Unfortunately, it is typical that they reach high school, where they first encounter formal studies in biology, chemistry, and physics, without significant exposure to science or problem-solving experiences. Because they did not enjoy what little science was included in the elementary and middle school curriculum, they regard science as dull and difficult, and they avoid it whenever possible.

Mathematics — the basic "language" of science — is too often confined in the elementary grades to arithmetic drill. Moreover, it is too seldom viewed as a vehicle for transmitting to children the reasoning and problem-solving skills that are needed in a technological age. As a result, U.S. children perform less well than children from all but the most underdeveloped countries on tests of mathematics understanding.

The Subactivity addresses these problems by 1) supporting the development of improved curriculum alternatives to help schools introduce science concepts and mathematical problem solving in the earliest years; 2) providing, through research, insight into the processes of teaching and learning; 3) helping to encourage early science concepts, experience and enthusiasm outside of school, through such means as television and museums; and 4) investigating the applications of new technologies to instruction.

Eleven large-scale curriculum projects, for example, are developing consistent and coherent science materials for elementary and middle schools. Each combines the efforts of scientists, science educators, school systems, and publishers who co-invest both human and financial resources to develop alternative science programs that can be implemented in typical schools. In the coming years, this pattern will be extended to the high school level. Other projects are testing models for improving middle school mathematics instruction and upgrading the quality of disciplinary courses.

Outside of school, the large audiences for TV series like *Square One TV* and *The Mind* will be complemented by continuing growth in the number and range of science museum projects. Support will be provided for traveling exhibit development by several museum consortia and for a wide range of permanent science museum exhibitions. Informal education support has stimulated the development of major out-of-school science education programs by children's organizations.

These practical efforts are closely linked to longer-term research that is increasing our understanding of how children learn and how they may be taught better. Another long-term concern is the potential impact of advanced educational technologies. Classroom computer-based environments show promise as intelligent tutors of algebra, geometry, and calculus; software systems that guide the learning of statistics and computer science are currently being developed and tested.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
Instructional Materials Development	$18.50	$21.50	$21.20	-$0.30	-1.4%
Research in Teaching and Learning	4.50	5.00	4.80	-0.20	-4.0
Informal Science Education.	15.00	16.00	15.70	-0.30	-1.9
Applications of Advanced Technology	5.99	6.50	6.30	-0.20	-3.1
Total, Subactivity	$43.99	$49.00	$48.00	-$1.00	-2.0%

The FY 1990 Current Plan is $1.0 million less than the FY 1990 Request of $49.0 million, and $4.01 million more than FY 1989, a 9.1 percent increase. Reductions were taken from the FY 1990 Request of each program of the Subactivity to comply with the Gramm-Rudman-Hollings sequestration. The Subactivity will carry out, at a slightly reduced level, the projects proposed in the FY 1990 Request.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Instructional Materials Development	$21.20	$31.00	$9.80	46.2%
Research in Teaching and Learning	4.80	5.00	$0.20	4.2
Informal Science Education	15.70	19.00	$3.30	21.0
Applications of Advanced Technology	6.30	6.50	$0.20	3.2
Total, Subactivity	$48.00	$61.50	$13.50	28.1%

The FY 1991 Budget Request is $13.5 million more than the FY 1990 Current Plan of $48.0 million.

The 28.1% increment will support the following increased efforts:

- Expansion into middle school mathematics of the scientist/educator/publisher model for curriculum projects;
- Continuation of instructional materials development programs that address science and mathematics curricula at all K-12 levels, addressing particularly the special needs of women, minorities, and the disabled;
- Development of curricula and instructional materials that integrate the science disciplines and mathematics into a coherent entity;
- Continuation of support for major television series on science and mathematics for children and adults; and
- Expansion of support for museum and science center activities that enrich out-of-school, hands-on experiences for children and adults.

UNDERGRADUATE SCIENCE, ENGINEERING, AND MATHEMATICS EDUCATION $50,000,000

SUMMARY OF REQUEST

The FY 1991 Request for the Undergraduate Science, Engineering, and Mathematics Education (USEME) Subactivity is $50.0 million, an increase of $16.0 million, or 47.1 percent, over the FY 1990 Current Plan of $34.0 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Instrumentation and Laboratory Improvement	$16.00	$16.00	$15.80	$23.00
Faculty Enhancement	3.00	3.00	2.90	4.00
Career Access Opportunities in Science and Technology for Women, Minorities, and the Disabled	5.00	7.00	11.30	15.00
Course and Curriculum	4.00	4.00	4.00	8.00
Total, Subactivity	$28.00	$30.00	$34.00	$50.00

EDUCATIONAL OVERVIEW

The National Science Foundation (NSF) has established a permanent and evolving Agency-wide effort to support fresh, high quality approaches to undergraduate science, engineering, and mathematics education. Undergraduate education is the essential bridge between the secondary schools and both professional careers and graduate education. Undergraduate education is a vital part of the U.S. scientific and technological enterprise because:

- it is the primary professional training for engineers and scientists, their technically trained assistants, and others who use science and technology in their work; and
- it is the last formal exposure to science for the non-science majors who may become the future leaders of business, Government, and the professions, and for all American citizens who will live in an increasingly technology-based society.

The 1986 National Science Board Report, "Undergraduate Science, Mathematics, and Engineering Education," identified pressing needs for improvement in the quality of undergraduate instruction. The Foundation responded to this report by developing a coherent Foundation-wide approach based on two major components: leadership, and leveraged program support.

The Division of Undergraduate Science, Engineering, and Mathematics Education was established in 1987 to serve as the focal point for NSF's efforts at the undergraduate level. The Division has three major areas of responsibility:

- Program management and operation of those undergraduate activities assigned to the Science and Engineering Education Activity;
- Coordination of all the Foundation's undergraduate support activities;
- Stimulation of further involvement of academic scientists and their institutions, the States, the private sector, and other federal agencies in improving undergraduate science, engineering and mathematics education.

USEME efforts focus on the following areas: laboratories, curriculum, faculty, students, and underrepresented groups.

- Laboratories: the Instrumentation and Laboratory Improvement component focuses on strengthening the undergraduate laboratory experience at all types of institutions. Matching grants enable grantees to purchase instructional instrumentation to generate more effective and innovative approaches to laboratory (or field) instruction. Projects are supported that result in a clear improvement of the laboratory curriculum and instruction, and thus the quality of undergraduate education.
- Faculty: The Undergraduate Faculty Enhancement Program sustains and enhances the vitality of teaching faculty at all types of colleges throughout the country. It brings them recent scientific and technical advances in their fields and helps them to incorporate such advances into their undergraduate courses. Topical conferences, seminars, and workshops provide valuable opportunities for faculty to interact with persons from industry and other faculty working at the frontiers of new developments and techniques in their fields.
- Course and Curriculum Development: The program began in FY 1988 with a focus on engineering and calculus. Partial support for these efforts has been provided by the Engineering Activity and the Mathematics and Physical Sciences Activity, respectively.

  In FY 1990, the engineering program was expanded through a special targeted solicitation, "Engineering Education Coalitions", supported jointly by SEE and the Engineering Activity. The coalitions seek to encourage dramatic improvement in the quality of undergraduate engineering education and to increase undergraduate engineering enrollments.

  Also beginning in FY 1990, SEE has coordinated an extended program to support undergraduate curriculum development in all disciplines supported by NSF. This extended program is supported primarily by the Research and Related Activities.
- Underrepresented Groups: The Career Access Program supports efforts to increase the entry of women, minorities, and the disabled into the pipeline toward scientific careers. Projects supported are of two major types: NSF Comprehensive Regional Centers for Minorities support partnerships among universities, two- and four-year colleges, and large, urban, heavily minority school districts to establish major science education centers for minority students, beginning with kindergarten and continuing through college; and Prototype and Model Projects are designed to improve the capability of colleges and universities to increase the numbers of underrepresented students who pursue studies for careers in science, engineering, and mathematics.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change Amount	Change Percent
College Science Instrumentation	$16.00	$16.00	$15.80	-$0.20	-1.2%
Faculty Enhancement	3.00	3.00	2.90	-0.10	-3.3
Career Access Opportunities in Science and Technology for Women, Minorities, and the Disabled	5.00	7.00	11.30	4.30	61.4
Course and Curriculum	4.00	4.00	4.00	0.00	0.0
Total, Subactivity	$28.00	$30.00	$34.00	$4.00	13.3%

The FY 1990 Current Plan is $4.0 million more than the FY 1990 Request of $30.0 million, and $6.0 million more than FY 1989, a 21.4 percent increase. This will allow continuing support of all the activities planned in the FY 1990 Request.

The increase of $4.3 million to the Career Access Opportunities Program, as specified by Congress, allows USEME to add in FY 1990 three to four centers to the existing eight comprehensive regional centers for minorities.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Instrumentation and Laboratory Improvement	$15.80	$23.00	$7.20	45.6%
Faculty Enhancement	2.90	4.00	1.10	37.9
Career Access Opportunities in Science and Technology for Women, Minorities, and the Disabled	11.30	15.00	3.70	32.7
Course and Curriculum	4.00	8.00	4.00	100.0
Total, Subactivity	$34.00	$50.00	$16.00	47.1%

The FY 1991 Request of $50.0 million is an increase of $16.0 million over the FY 1990 Current Plan. This increase will be used to expand support for critical needs in undergraduate education in all USEME programs.

The Instrumentation and Laboratory Improvement (ILI) program enables institutions to develop fresh and more effective approaches to laboratory instruction. In FY 1991, ILI will support laboratory development (instrument-based or not) at all types of institutions. The College Science Instrumentation Program, a component of ILI, will total $16.0 million.

Expansion of the Faculty Enhancement Program will increase support for workshops, seminars, and conferences enabling additional groups of faculty, especially two-year college faculty, to learn about new developments and new techniques in their fields.

The Career Access Program supports the NSF Comprehensive Regional Centers for Minorities. The increase will provide continued support for the approximately twelve centers initiated since FY 1988, and support at the initial level for three to four additional centers.

The FY 1991 Request doubles support over FY 1990 for undergraduate course and curriculum development (from $4.0 million to $8.0 million in SEE; from $12.33 million to $27.48 million in R&RA) and expands the effort to include all fields of science, mathematics and engineering.

USEME will continue to manage and coordinate these NSF-wide programs and activities and to exercise its leadership and collaboration role with undergraduate programs in the Research Directorates throughout the Foundation. The NSF-wide undergraduate education and research programs will be incremented by $43.8 million, for a total of $134.2 million.

CHANGES IN THE BUDGET STRUCTURE

The College Science Instrumentation Program (CSIP) is expanded and renamed Instrumentation and Laboratory Improvement (ILI). CSIP remains an integral component of ILI, at a FY 1991 Request level of $16 million.

RESEARCH CAREER DEVELOPMENT $44,900,000

SUMMARY OF REQUEST

The FY 1991 Request for the Research Career Development (RCD) Subactivity is $44.9 million, an increase of $8.0 million, or 21.7 percent, over the FY 1990 Current Plan of $36.9 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Graduate Fellowships	$21.58	$28.00	$25.40	$30.50
Minority Graduate Fellowships	2.40	3.00	4.50	5.40
Young Scholars (Precollege)	7.00	7.00	7.00	9.00
Total, Subactivity	$30.98	$38.00	$36.90	$44.90

EDUCATIONAL OVERVIEW

The Research Career Development Subactivity promotes the career development of young scientists and engineers, and thereby helps to assure a steady flow of high-ability students through the educational and research training systems of the Nation. This objective is addressed through the Graduate Research Fellowships Program, comprising Graduate Fellowships, Minority Graduate Fellowships and Graduate Fellowships for Women in Engineering, which promotes the future strength of the Nation's scientific endeavors by recognizing and supporting the most promising graduate students; and through the Young Scholars Program, which provides summer and academic-year enrichment opportunities for high potential junior and senior high school students who have the ability to pursue careers in science and engineering.

In the Research Fellowships Programs highly talented U.S. citizens who are at or near the beginning of their graduate study are identified in a national competition. Fellowship awards provide stipends and cost-of-education allowances (institutional allowances in lieu of tuition and fees). Up to three years of support are offered to outstanding graduate students for study at institutions of their choice. Full-time study support of this kind has historically accelerated Fellows' progress toward active and distinguished science and engineering careers. This support is made available in recognition of the importance of science and technology to the security and well-being of the Nation.

Awards for these portable fellowships are made on the basis of merit in all fields of science and engineering. Within this framework, support is also provided for graduate students who are members of ethnic minority groups underrepresented in science and technology, and for women in engineering, in recognition of the under-representation of females in the advanced levels of engineering. This latter component is a cooperative effort of the Science and Engineering Education Activity and the Engineering Activity.

NSF Graduate Research Fellowships are among the most visible of NSF programs. The difficult national competition, the flexibility afforded Fellows under the terms of the program, and the career success records of former Fellows make NSF Fellows highly sought on the Nation's campuses. The visibility of successful applicants exerts a strong influence on younger students contemplating careers in science and engineering. The selection of outstanding students to be Fellows in all fields of science and engineering helps prepare the Nation to face the research challenges of the next generation.

NSF has awarded over 25,000 Graduate Research Fellowships since the inception of the activity in 1952. Former Fellows have to date won 12 Nobel Prizes, 6 Fields Medals and 7 Waterman Awards, including the 1989 Nobel Prize in physics to Dr. Thomas Cech. This record of achievement is evidence of the Nation's significant return on its investment in these outstanding young scientists and engineers.

NSF Graduate Research Fellowships complement the graduate fellowship programs of several other federal agencies. NSF is the only agency that provides this type of support across all science and engineering fields, a characteristic linked to the national recognition aspect of the awards. Other agencies target particular areas of science and engineering, a characteristic consistent with their more focussed missions. Close and regular communication is maintained among the program staffs of NSF and other fellowship-granting agencies.

The Young Scholars Program stimulates the flow of talented students into the beginning of the pipeline leading to academic excellence. The junior and senior high school years are for many students the decisive period that determines career patterns. It is important to the Nation that talented students of this age group have a full opportunity for exposure to the excitement of science as they make their career decisions. For many students the summer or school-year experience supported by this program will offer opportunities to sharpen their academic competitiveness, and provide stimulation to become scientists and engineers. In the Summer of 1990, the Young Scholars Program, which was initiated in 1988, will reach an estimated 4,500 young students in a wide variety of intellectually challenging projects.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Graduate Fellowships	$21.58	$28.00	$25.40	-$2.60	-9.3%
Minority Graduate Fellowships	2.40	3.00	4.50	1.50	50.0
Young Scholars (Pre-college)	7.00	7.00	7.00	0.00	0.0
Total, Subactivity	$30.98	$38.00	$36.90	-$1.10	-2.9%

The FY 1990 Current Plan is $1.1 million less than the FY 1990 Request of $38.0 million, and $5.92 million more than FY 1989, a 19.1 percent increase. Since this reduction from the FY 1990 Request can be accommodated by recent variations in offered awards that have not been accepted, the Graduate Fellowship Management Plan will continue to be implemented as outlined in the FY 1990 Request. The number of new three-year graduate fellowship award offers will increase from 860 to 960, and approximately 2280 students will receive such fellowship support in the FY 1990-1991 academic year. The proportion of fellowships made under the Minority Graduate Fellowship component will be increased.

The Young Scholars FY 1990 Current Plan is $7.0 million, as requested, and will involve over 4500 students in FY 1990 projects.

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change	
			Amount	Percent
Graduate Fellowships	$25.40	$30.50	$5.10	20.1%
Minority Graduate Fellowships	4.50	5.40	0.90	20.0
Young Scholars (Precollege)	7.00	9.00	2.00	28.6
Total, Subactivity	$36.90	$44.90	$8.00	21.7%

The amount requested for FY 1991 represents an increase of 21.7% over the FY 1990 Current Plan, consistent with the Foundation's planned four-year doubling of the Fellowship Programs. Specifically, this plan allows an increase of 100 new Graduate Research Fellowships and an increase of $2.0 million, or 28.6 percent, in the Young Scholars Program. The latter effort was initiated in FY 1988 for high ability and high potential junior and senior high school students who might otherwise be lost to advanced study in science and engineering.

In FY 1991 the funding for Graduate and Minority Graduate Research Fellowships will increase by $6.0 million. The Research Career Development Subactivity will increase the number of new three-year graduate fellowship awards from 920 to 1020 for the Graduate and Minority Graduate Fellowships Programs; in addition, 40 Graduate Fellowships for Women in Engineering, supported by the Science and Engineering Education Activity, plus 40 more supported by the Engineering Activity, will be awarded. The new program of Graduate Fellowships for Women in Engineering, initiated in FY 1990, addresses the problem of the very low percent of engineering faculty members who are women. A minimum of 15 percent of the new Graduate Research Fellowships will be made to minority students, primarily through the Minority Graduate Fellowship component. Including commitments from prior years, approximately 2560 students in total will receive such fellowship support in the 1991-1992 academic year.

The annual stipend for Graduate Research Fellowships will be increased to $13,500 in FY 1991, and the cost-of-education allowance, provided to the fellowship institution in lieu of tuition and fees, remains at $6,000.

FY 1991 is the final of three annual steps planned in a transition from the current schedule for obligating funds in which obligation of funds is made in the fiscal year in which fellowship commitments are made, to obligation of funds in the fiscal year in which tenure is primarily exercised. Thus, commitments to the 2560 Graduate Fellows referenced above will be made in FY 1991, but the Fellows will actually be supported from the FY 1992 appropriation. The effect of the planned stipend increase coupled with the administrative transition is detailed in the following table.

SEE-FUNDED FELLOWSHIP MANAGEMENT PLAN*

(Millions of Dollars)

	FY88	FY89	FY90	FY91	FY92	FY93
New Awards	760	860	960	1060	1060	1060
Est. Fellows on Tenure	1650	1865	2280	2560	2750	2850
Current Payment Schedule	$30.3	$37.9	$47.2	$55.2	$59.7	$61.8
Adjusted Payment Schedule	$30.3	$24.0	$29.9	$35.9	$56.6	$61.8

*Does not include Fellowships funded by Engineering Activity.

For FY 1991 the Young Scholars Program will be increased by $2.0 million. This funding will make possible an increase in the annual two-year awards to approximately 100, and the annual involvement of approximately 6,500 students nationwide.

STUDIES AND PROGRAM ASSESSMENT *$5,000,000*

The FY 1991 Request for the Studies and Program Assessment (SPA) Subactivity is $5.0 million, an increase of $630,000, or 14.4 percent, over the FY 1990 Current Plan of $4.37 million.

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	FY 1991 Request
Studies and Analyses	$4.50	$4.50	$4.37	$5.00
Total, Subactivity	$4.50	$4.50	$4.37	$5.00

EDUCATIONAL OVERVIEW

This Subactivity serves as a source of data and evaluation information about science, mathematics, and engineering education in the United States, and provides analytical and policy studies to support the education leadership efforts of the Foundation. The Subactivity has two components:

- Studies and Analysis: Projects are supported which provide data on national trends and other information to assist the Foundation and other agencies in developing initiatives to strengthen science, mathematics, and engineering education in the United States.
- Program Assessment: Evaluation activities are supported in conjunction with NSF's science and mathematics education programs to assist them and the SEE Activity in program planning.

The Studies and Analyses Program is designed to: (a) provide data of national scope on significant problems in science, mathematics, and engineering, that would be useful for policy deliberations regarding the strengthening of S&E education in the United States; and (b) provide information that will assist in setting priorities and plans for the Foundation's science education programs. For example, an international assessment of science and mathematics achievement released in 1989 (and supported by NSF) revealed that U.S. 13-year-olds ranked lowest in mathematics among the 12 populations tested. (The study involved Korea, Spain, Ireland, United States, United Kingdom, and English- and French-speaking students in four Canadian provinces.) The United States ranked ninth in science achievement.

The Program Assessment component supports studies to assist project and program staff in improving their efforts, and to provide the public and the science education community with greater understanding of the effectiveness of specific education programs. Assessment studies are currently being implemented for programs such as the College Science Instrumentation Program; the

Young Scholars Program; Career Access Opportunities in Science and Technology for Women, Minorities, and the Disabled; and the Graduate and Minority Graduate Fellowships Programs.

SEE recognizes that other NSF Activities and other federal agencies, especially the Department of Education, have responsibility for collecting primary data on such topics as supply and demand for professional scientists, mathematicians, and engineers; supply and demand for faculty at various levels; and students' educational achievement and participation. In these areas, SEE collaborates with the other organizations in the collection and interpretation of primary data, or supports syntheses and secondary data analyses, rather than perform its own primary data collection. In areas of special interest to science education, NSF sponsors enhancements of new or continuing projects (e.g., enlarged sample sizes, experiments in developing new testing procedures and analyses, and interpretation of data through ongoing studies).

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

Program Element	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Percent
Studies and Analyses	$4.50	$4.50	$4.37	-$0.13	-2.9%
Total, Subactivity	$4.50	$4.50	$4.37	-$0.13	-2.9%

The FY 1990 Current Plan is $130,000, or 2.9 percent, less than the FY 1990 Request. With minor reduction, this plan will still permit the Subactivity to carry out the programs proposed in the FY 1990 Request, including: establishing indicator systems for monitoring mathematics and science education; assessing student achievement trends in mathematics and science, in the U.S. and in other industrialized countries; and supporting data gathering and policy studies in several areas strongly related to nationwide education improvement efforts (e.g., the supply and training of scientists, mathematicians, and engineers; and teacher education, qualification, supply, and demand).

FY 1991 BUDGET REQUEST

(Millions of Dollars)

Program Element	FY 1990 Current Plan	FY 1991 Request	Change Amount	Change Percent
Studies and Analyses	$4.37	$5.00	$0.63	14.4%
Total, Subactivity	$4.37	$5.00	$0.63	14.4%

The FY 1990 Budget Request is $630,000 more than the FY 1990 Current Plan of $4.37 million. This budget will support the following activities:

- National and international comparative studies of science education; and dissemination of such information among agencies and organizations responsible for education policy at various levels (national, state, and local).
- Policy studies related to education improvement and reform initiatives at the local and state levels, e.g., teacher preparation and professional enhancement, the application of information technologies to education, and school structure and restructuring efforts.
- Assessment and data collection efforts related to the Foundation's science and engineering education programs, including teacher preparation and enhancement, materials development, high leverage programs, minority access to science education, and incentives for young science scholars.
- Assistance to states and local school districts to develop effective evaluation methods for student progress and for science and mathematics education programs and materials.

OFFICE OF INSPECTOR GENERAL..$3,000,000

SUMMARY OF REQUEST

The FY 1991 request for the Office of Inspector General (OIG) Activity is $3.0 million, an overall increase of $440,000 or 17.2% over the FY 1990 Current Plan of $2.56 million.

(Millions of Dollars)

Activity	FY 1989 Actual	FY 1990 Request[1]	FY 1990 Current Plan	FY 1991 Request
Personnel Compensation & Benefits	$1.11	$1.27	$1.39	$1.57
Other Operating Expenses	1.11	1.38	1.17	1.43
Total	$2.22	$2.65	$2.56	$3.00
FULL-TIME EQUIVALENT EMPLOYMENT:				
Full-Time Equivalent (FTE)	19	23	25	27

[1] The request for FY 1990 was contained within thePD&M activity

BACKGROUND

The National Science Board established the Office of Inspector General for NSF pursuant to the Inspector General Act of 1978, as amended. The Board transferred most of the staff from the NSF Office of Audit and Oversight to the newly established OIG. On April 12, 1989, the Board appointed NSF's first Inspector General. The statute provides the Office of Inspector General with the responsibility and the authority to:

- Conduct and supervise audits and investigations of NSF programs and operations;
- Provide leadership and coordination and recommend policies for activities designed to:

  (a) promote economy, efficiency and effectiveness in the administration of NSF programs and operations, and

  (b) prevent and detect fraud and abuse in NSF programs and operations; and
- Provide a means for keeping NSF and the Congress fully and currently informed about problems and deficiencies relating to the administration of NSF programs and operations and the necessity for and progress of corrective action.

The OIG is responsible for audit and oversight of the financial, administrative, and programmatic aspects of NSF's activities. The office serves as the focal point of contacts with other federal audit organizations in the Executive Branch and with the General Accounting Office (GAO) regarding audit and oversight activities.

The OIG is comprised of three Offices: External Audit, Internal Audit and Investigations, and Oversight. The External Audit Office is responsible for the performance of audits of NSF grants and contracts at universities and commercial and nonprofit organizations, and for following up on the implementation of recommendations included in audit reports. It is also responsible for pre-award audits and for recommending to NSF's Division of Grants and Contracts final indirect cost rates applicable to NSF awards.

The Office of Internal Audit and Investigations is responsible for reviewing and evaluating the financial, administrative, and programmatic aspects of NSF activities. This includes the evaluation of internal controls and data processing systems; investigating charges of criminal and administrative violations by NSF staff and funded organizations; and following-up on the implementation of recommendations included in both NSF and GAO audit reports.

The Office of Oversight is responsible for reviewing, evaluating, and reporting to NSF management on the administrative, procedural, and policy aspects of proposal actions in NSF programs; monitoring the schedule and the process of external peer oversight; ensuring adherence to NSF conflicts-of-interest regulations as they apply to new and former employees; monitoring the NSF formal reconsideration process; evaluating charges of misconduct in science; and assessing overall system performance and recommending improvements.

CHANGES BETWEEN FY 1990 REQUEST AND FY 1990 CURRENT PLAN

(Millions of Dollars)

	FY 1989 Actual	FY 1990 Request	FY 1990 Current Plan	Change	
				Amount	Plan
Personnel Compensation and Benefits	$1.11	$1.27	$1.39	$0.12	9.4%
Other Operating Expenses	1.11	1.38	1.17	-0.21	-15.2
Total	$2.22	$2.65	$2.56	$-0.09	-3.4%

The reduction from the request represents the share of the Gramm-Rudman-Hollings sequestration and the other Congressionally-mandated reductions.

The major initiative in the external audit area is for increasing the OIG's in-house external audit capability. In the past, approximately 95% of the Foundation's cost and compliance audit work has been conducted either by private audit firms under contract to NSF, or auditors employed by other Federal agencies.

With an in-house audit staff this office plans to provide these services with greater responsiveness and at a reduced cost. Additional auditors were hired in 1989, and currently, staffing plans contemplate the hiring of additional external auditors in FY 1990 and FY 1991. With this increased staffing complement, the OIG plans to provide the Foundation with an audit staff capable of undertaking up to 30% of the agency's cost and compliance audits by the close of FY 1991.

The OIG oversight responsibilities are being broadened and staffing increased in response to several concerns. Congressional interest in the area of scientific misconduct has resulted in a new emphasis on gathering data to assess the scope of the problem and developing investigative techniques to resolve allegations when they arise. Changes in conflicts-of-interests laws and regulations create new difficulties for the Foundation, which is committed to the concept of "rotation" of scientists from the private to the public sector for limited periods. In conjunction with the Office of General Counsel and other NSF staff, this Office will be working with program personnel to help ensure compliance with applicable laws and regulations in a way which will not impinge upon the free exchange of scientific, engineering, and education expertise.

The FY 1990 FTE level of 25 represents an increase of six over the FY 1989 level. The 1990 Current Plan funding estimate includes resources for personnel compensation and benefits, travel, audit contracts, and office supplies, materials and equipment.

FY 1991 BUDGET REQUEST

An increase of $440,000 over the 1990 Current Plan is requested for the Office of Inspector General in 1991.

Activity	FY 1989 Actual	FY 1990 Current Plan	FY 1991 Request	DIFFERENCE FY 90/91
Personnel Compensation & Benefits	$1,122,280	$1,392,000	$1,564,000	$172,000
Travel and transportation of persons	21,947	45,000	50,000	$5,000
Rental payments to GSA	0	0	163,000	$163,000
Communication, utilities, and miscellaneous charges	0	0	42,000	$42,000
Printing and Reproduction	1,000	1,000	1,000	$ 0
Other services	1,018,302	1,076,000	1,134,000	$58,000
Supplies and materials	6,127	6,000	6,000	$ 0
Equipment	49,646	40,000	40,000	$ 0
Total	$2,219,302	$2,560,000	$3,000,000	$440,000

Since the Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990, (Public Law 101-144), provides for a separate appropriation for the NSF Office of Inspector General, the 1991 request represents the resources needed to support the Office of Inspector General. These resources include amounts for personnel compensation and benefits, space rental, postage, communications, audit contracts, and office supplies, materials and equipment.

Personnel compensation and benefits costs will increase by $172,000 or 12.4% over the 1990 request. The increase requested for salaries and benefits reflects the cost of pay raises and the funding to support 27 FTE, an increase of 2 FTE over the 1990 level. External audit services will remain at the 1990 level of $1 million. Other operating expenses increase by $268,000 primarily due to the initial payment of rent ($163,000) and communications ($42,000) costs in 1991.

The table showing the detail of permanent positions is a summary of Permanent Positions as of the end of FY 1989 and estimated to be filled at the end of FY 1990 and FY 1991. OMB Circular No. A-11 (Section 51.2) defines "permanent positions" as those which are occupied or to be occupied by full-time employees with permanent appointments.

Detail of Permanent Positions

	FY 1989 Actual	FY 1990 Estimate	FY 1991 Estimate
ES-5	1	1	1
Subtotal	1	1	1
AD	1	3	3
GS/GM-15	2	2	2
GS/GM-14	4	5	5
GS/GM-13	5	5	6
GS-12	1	2	3
GS-11	–	1	1
GS-10	–	–	–
GS-9	–	–	1
GS-8	2	2	2
GS-7	3	3	3
GS-6	1	1	–
Subtotal	18	21	23
Total Permanent Positions	20	25	27

NATIONAL SCIENCE FOUNDATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$1,562,628,928	$1,651,009,065	$1,853,208,600
Applied Research	107,767,166	114,829,778	130,143,400
Development	0	0	0
Subtotal, Conduct of R&D	1,670,396,094	1,765,838,843	1,983,352,000
(Conduct of R&D Performed by Colleges and Universities.)	(1,260,070,730)	(1,323,562,252)	(1,485,408,000)
R&D Facilities			
Land, Building and Fixed Equipment	18,094,754	45,329,053	90,825,000
Major Equipment	35,486,108	74,054,887	63,182,000
Subtotal, R&D Facilities & Major Equipment	53,580,862	119,383,940	154,007,000
Total, Support of R&D	1,723,976,956	1,885,222,783	2,137,359,000
Education and Training	155,771,501	188,570,000	234,600,000
Collection of Information	6,129,019	7,255,217	8,041,000
TOTAL	$1,885,877,476	$2,081,048,000	$2,380,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	44,315	47,340	52,320
Dollars Requested (Total)	$10,249,897,476	$10,855,560,046	$11,676,385,000
Action Summary			
Number of Awards	16,691	17,366	18,908
Dollars Obligated(Total)	1,885,877,476	2,081,048,000	2,380,000,000
Dollar Distribution by Performer			
Universities	1,383,666,114	1,473,561,843	1,721,942,000
Industry	75,020,778	93,095,298	117,385,000
Federal Agencies	81,018,655	85,430,337	88,213,700
Other	346,171,929	428,960,522	452,459,300
Personnel			
Senior Scientists			
Number of Scientists Supported	18,916	20,126	22,514
Amount of Scientist Support	206,601,383	221,144,952	251,273,000
Number of Years of Scientist Support	3,986	4,259	4,763
Postdoctoral Support			
Number of Postdoctorals Supported	3,636	3,781	4,153
Amount Postdoctoral Support	67,319,490	69,646,153	76,656,800
Graduate Students			
Number of Graduate Students Supported	15,593	17,030	18,987
Amount Graduate Student Support	169,094,805	183,090,389	206,914,000
Other Personnel Costs			
Amount of Support	278,690,344	296,558,052	333,964,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	17,182,019	44,365,312	94,800,000
Major Equipment	32,798,664	71,170,687	59,760,000
Other Equipment and Instrumentation	200,254,716	215,446,806	247,430,800
Other Direct Research Costs*	475,544,050	516,751,643	590,233,000
Indirect Costs	438,392,004	462,874,006	518,968,400
TOTAL	$1,885,877,476	$2,081,048,000	$2,380,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, Fringe Benefits.

RESEARCH AND RELATED ACTIVITIES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$1,437,239,087	$1,508,540,965	$1,692,261,600
Applied Research	99,604,402	106,747,919	121,620,400
Development	0	0	0
Subtotal,Conduct of R&D	1,536,843,489	1,615,288,884	1,813,882,000
(Conduct of R&D Performed by Colleges and Universities.)	(1,233,565,197)	(1,295,220,533)	(1,453,817,000)
R&D Facilities			
Land, Building and Fixed Equipment	5,222,754	28,502,012	68,895,000
Major Equipment	35,486,108	74,054,887	63,182,000
Subtotal, R&D Facilities & Major Equipment	40,708,862	102,556,899	132,077,000
Total, Support of R&D	1,577,552,351	1,717,845,783	1,945,959,000
Education and Training	0	0	0
Collection of Information	6,129,019	7,255,217	8,041,000
TOTAL	$1,583,681,370	$1,725,101,000	$1,954,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	34,305	35,431	38,596
Dollars Requested (Total)	$9,123,111,097	$9,606,454,147	$10,298,788,000
Action Summary			
Number of Awards	15,097	15,668	17,018
Dollars Obligated(Total)	1,583,681,370	1,725,101,000	1,954,000,000
Dollar Distribution by Performer			
Universities	1,253,855,798	1,322,639,944	1,537,468,000
Industry	29,713,680	31,956,746	36,002,000
Federal Agencies	6,699,655	7,430,762	8,833,700
Other	293,412,237	363,073,548	371,696,300
Personnel			
Senior Scientists			
Number of Scientists Supported	16,036	16,838	18,686
Amount of Scientist Support	182,332,776	192,322,295	216,302,000
Number of Years of Scientist Support	3,393	3,566	3,941
Postdoctoral Support			
Number of Postdoctorals Supported	3,497	3,620	3,947
Amount Postdoctoral Support	65,979,668	68,140,978	74,835,000
Graduate Students			
Number of Graduate Students Supported	13,710	14,379	15,719
Amount Graduate Student Support	144,204,563	151,868,694	169,136,000
Other Personnel Costs			
Amount of Support	227,929,619	238,855,028	267,236,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	4,310,019	27,538,312	67,870,000
Major Equipment	32,798,664	71,170,687	59,760,000
Other Equipment and Instrumentation	166,976,882	177,329,072	201,304,000
Other Direct Research Costs*	347,782,337	366,814,707	416,345,000
Indirect Costs	411,366,841	431,061,227	481,212,000
TOTAL	$1,583,681,370	$1,725,101,000	$1,954,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, Fringe Benefits.

BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$264,770,289	$275,797,349	$305,568,000
Applied Research	15,383,185	16,184,651	18,367,000
Development	0	0	0
Subtotal, Conduct of R&D	280,153,474	291,982,000	323,935,000
(Conduct of R&D Performed by Colleges and Universities.)	(252,161,225)	(262,774,935)	(292,804,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	1,315,668	1,553,000	3,590,000
Subtotal, R&D Facilities & Major Equipment	1,315,668	1,553,000	3,590,000
Total, Support of R&D	281,469,142	293,535,000	327,525,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$281,469,142	$293,535,000	$327,525,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	9,962	10,206	11,118
Dollars Requested (Total)	2,537,680,256	2,629,919,260	$2,872,352,000
Action Summary			
Number of Awards	3,971	4,118	4,507
Dollars Obligated(Total)	281,469,142	293,535,000	327,525,000
Average Award Size	70,881	71,000	73,000
Dollar Distribution by Performer			
Universities	253,306,225	264,126,859	295,218,000
Industry	581,592	605,880	667,000
Federal Agencies	133,868	137,041	147,000
Other	27,447,457	28,665,220	31,493,000
Personnel			
Senior Scientists			
Number of Scientists Supported	2,879	3,020	3,300
Amount of Scientist Support	33,743,571	35,185,712	38,974,000
Number of Years of Scientist Support	813	845	931
Postdoctoral Support			
Number of Postdoctorals Supported	911	950	1,053
Amount Postdoctoral Support	18,578,335	19,302,154	21,534,000
Graduate Students			
Number of Graduate Students Supported	2,068	2,149	2,364
Amount Graduate Student Support	18,808,445	19,534,228	21,555,000
Other Personnel Costs			
Amount of Support	49,370,860	51,456,332	57,026,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	1,315,668	1,553,000	3,590,000
Other Equipment and Instrumentation	32,817,971	34,394,848	38,246,000
Other Direct Research Costs*	56,605,536	59,012,035	65,381,000
Indirect Costs	70,228,756	73,096,691	81,221,000
TOTAL	$281,469,142	$293,535,000	$327,525,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, Fringe Benefits.

MOLECULAR BIOSCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$46,399,685	$47,731,000	$51,625,000
Applied Research	303,782	312,000	338,000
Development	0	0	0
Subtotal, Conduct of R&D	46,703,467	48,043,000	51,963,000
(Conduct of R&D Performed by Colleges and Universities.)	(42,151,525)	(43,360,501)	(46,898,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	46,703,467	48,043,000	51,963,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$46,703,467	$48,043,000	$51,963,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,483	1,526	1,650
Dollars Requested (Total)	$533,246,592	$548,540,990	$593,298,000
Action Summary			
Number of Awards	599	614	664
Dollars Obligated(Total)	46,703,467	48,043,000	51,963,000
Average Award Size	77,969	78,000	78,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	42,151,525	43,360,501	46,898,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	4,551,942	4,682,499	5,065,000
Personnel			
Senior Scientists			
Number of Scientists Supported	367	378	408
Amount of Scientist Support	4,528,590	4,658,477	5,039,000
Number of Years of Scientist Support	112	115	125
Postdoctoral Support			
Number of Postdoctorals Supported	274	282	305
Amount Postdoctoral Support	5,465,060	5,621,807	6,081,000
Graduate Students			
Number of Graduate Students Supported	359	369	399
Amount Graduate Student Support	3,893,012	4,004,670	4,331,000
Other Personnel Costs			
Amount of Support	8,039,948	8,270,547	8,945,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,388,167	2,456,664	2,657,000
Other Direct Research Costs*	8,785,269	9,037,245	9,775,000
Indirect Costs	13,603,421	13,993,590	15,135,000
TOTAL	$46,703,467	$48,043,000	$51,963,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

CELLULAR BIOSCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$54,803,044	$56,573,842	$62,247,000
Applied Research	728,615	752,158	828,000
Development	0	0	0
Subtotal, Conduct of R&D	55,531,659	57,326,000	63,075,000
(Conduct of R&D Performed by Colleges and Universities.)	(52,822,874)	(54,529,609)	(59,998,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	55,531,659	57,326,000	63,075,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$55,531,659	$57,326,000	$63,075,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,949	2,012	2,214
Dollars Requested (Total)	$764,994,272	$789,712,795	$868,910,000
Action Summary			
Number of Awards	868	890	979
Dollars Obligated(Total)	55,531,659	57,326,000	63,075,000
Average Award Size	63,976	64,000	64,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	52,822,874	54,529,609	59,998,000
Industry	0	0	0
Federal Agencies	13,868	14,316	16,000
Other	2,694,917	2,781,995	3,061,000
Personnel			
Senior Scientists			
Number of Scientists Supported	497	513	565
Amount of Scientist Support	5,391,840	5,566,061	6,124,000
Number of Years of Scientist Support	131	135	149
Postdoctoral Support			
Number of Postdoctorals Supported	266	275	302
Amount Postdoctoral Support	5,702,175	5,886,424	6,477,000
Graduate Students			
Number of Graduate Students Supported	466	481	529
Amount Graduate Student Support	4,313,768	4,453,155	4,900,000
Other Personnel Costs			
Amount of Support	10,854,705	11,205,443	12,329,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,412,853	2,490,817	2,741,000
Other Direct Research Costs*	11,043,263	11,400,093	12,543,000
Indirect Costs	15,813,055	16,324,007	17,961,000
TOTAL	$55,531,659	$57,326,000	$63,075,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

BIOTIC SYSTEMS AND RESOURCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$58,647,622	$62,278,600	$68,516,000
Applied Research	4,167,390	4,425,400	4,869,000
Development	0	0	0
Subtotal, Conduct of R&D	62,815,012	66,704,000	73,385,000
(Conduct of R&D Performed by Colleges and Universities.)	(56,216,746)	(59,697,224)	(65,676,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	62,815,012	66,704,000	73,385,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$62,815,012	$66,704,000	$73,385,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,812	1,924	2,117
Dollars Requested (Total)	$350,064,624	$371,737,741	$408,971,000
Action Summary			
Number of Awards	779	827	910
Dollars Obligated(Total)	62,815,012	66,704,000	73,385,000
Average Award Size	80,635	80,658	81,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	56,216,746	59,697,224	65,676,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	6,598,266	7,006,776	7,709,000
Personnel			
Senior Scientists			
Number of Scientists Supported	701	744	819
Amount of Scientist Support	7,936,468	8,428,000	9,272,000
Number of Years of Scientist Support	204	217	238
Postdoctoral Support			
Number of Postdoctorals Supported	166	176	194
Amount Postdoctoral Support	3,163,773	3,359,600	3,696,000
Graduate Students			
Number of Graduate Students Supported	332	353	388
Amount Graduate Student Support	3,278,238	3,481,200	3,830,000
Other Personnel Costs			
Amount of Support	13,673,965	14,520,500	15,975,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	4,660,488	4,949,000	5,445,000
Other Direct Research Costs*	15,244,251	16,188,000	17,809,000
Indirect Costs	14,857,827	15,777,700	17,358,000
TOTAL	$62,815,012	$66,704,000	$73,385,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

BEHAVIORAL AND NEURAL SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$44,541,535	$45,553,159	$48,748,000
Applied Research	283,404	289,841	310,000
Development	0	0	0
Subtotal, Conduct of R&D	44,824,939	45,843,000	49,058,000
(Conduct of R&D Performed by Colleges and Universities.)	(42,382,643)	(43,345,235)	(46,385,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	44,824,939	45,843,000	49,058,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$44,824,939	$45,843,000	$49,058,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	2,124	2,172	2,325
Dollars Requested (Total)	$457,178,576	$467,561,985	$500,352,000
Action Summary			
Number of Awards	799	817	876
Dollars Obligated(Total)	44,824,939	45,843,000	49,058,000
Average Award Size	56,101	56,000	56,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	42,382,643	43,345,235	46,385,000
Industry	86,464	88,428	95,000
Federal Agencies	120,000	122,725	131,000
Other	2,235,832	2,286,612	2,447,000
Personnel			
Senior Scientists			
Number of Scientists Supported	479	490	524
Amount of Scientist Support	5,889,193	6,022,948	6,445,000
Number of Years of Scientist Support	182	186	199
Postdoctoral Support			
Number of Postdoctorals Supported	116	119	127
Amount Postdoctoral Support	2,307,774	2,360,188	2,526,000
Graduate Students			
Number of Graduate Students Supported	411	420	450
Amount Graduate Student Support	3,807,200	3,893,669	4,167,000
Other Personnel Costs			
Amount of Support	8,614,238	8,809,884	9,428,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,054,741	2,101,408	2,249,000
Other Direct Research Costs*	9,831,708	10,055,005	10,760,000
Indirect Costs	12,320,085	12,599,898	13,483,000
TOTAL	$44,824,939	$45,843,000	$49,058,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

SOCIAL AND ECONOMIC SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$22,714,178	$23,733,748	$26,111,000
Applied Research	8,159,019	8,525,252	9,379,000
Development	0	0	0
Subtotal, Conduct of R&D	30,873,197	32,259,000	35,490,000
(Conduct of R&D Performed by Colleges and Universities.)	(23,539,590)	(24,596,210)	(27,060,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	30,873,197	32,259,000	35,490,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$30,873,197	$32,259,000	$35,490,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,478	1,544	1,699
Dollars Requested (Total)	$302,047,120	$315,605,088	$347,215,000
Action Summary			
Number of Awards	510	533	586
Dollars Obligated(Total)	30,873,197	32,259,000	35,490,000
Average Award Size	60,535	61,000	61,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	23,539,590	24,596,210	27,060,000
Industry	423,445	442,452	487,000
Federal Agencies	0	0	0
Other	6,910,162	7,220,338	7,943,000
Personnel			
Senior Scientists			
Number of Scientists Supported	534	558	614
Amount of Scientist Support	6,702,377	7,003,226	7,705,000
Number of Years of Scientist Support	97	101	112
Postdoctoral Support			
Number of Postdoctorals Supported	39	41	45
Amount Postdoctoral Support	991,624	1,036,135	1,140,000
Graduate Students			
Number of Graduate Students Supported	420	439	483
Amount Graduate Student Support	2,722,337	2,844,534	3,129,000
Other Personnel Costs			
Amount of Support	4,187,016	4,374,958	4,813,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	801,004	836,959	921,000
Other Direct Research Costs*	7,054,057	7,370,692	8,109,000
Indirect Costs	8,414,782	8,792,496	9,673,000
TOTAL	$30,873,197	$32,259,000	$35,490,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

INSTRUMENTATION AND RESOURCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$35,207,543	$37,026,000	$41,617,000
Applied Research	1,363,325	1,434,000	1,612,000
Development	0	0	0
Subtotal, Conduct of R&D	36,570,868	38,460,000	43,229,000
(Conduct of R&D Performed by Colleges and Universities.)	(32,042,847)	(33,698,076)	(37,877,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	36,570,868	38,460,000	43,229,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$36,570,868	$38,460,000	$43,229,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	942	991	1,114
Dollars Requested (Total)	$129,947,938	$136,660,625	$153,606,000
Action Summary			
Number of Awards	414	435	489
Dollars Obligated(Total)	36,570,868	38,460,000	43,229,000
Average Award Size	88,335	88,000	88,000
Average Award Duration(Years)	1.4	1.4	1.4
Dollar Distribution by Performer			
Universities	32,042,847	33,698,000	37,876,000
Industry	71,683	75,000	85,000
Federal Agencies	0	0	0
Other	4,456,338	4,687,000	5,268,000
Personnel			
Senior Scientists			
Number of Scientists Supported	292	307	345
Amount of Scientist Support	2,976,063	3,130,000	3,518,000
Number of Years of Scientist Support	83	87	98
Postdoctoral Support			
Number of Postdoctorals Supported	36	38	43
Amount Postdoctoral Support	629,929	662,000	745,000
Graduate Students			
Number of Graduate Students Supported	67	70	79
Amount Graduate Student Support	626,490	659,000	741,000
Other Personnel Costs			
Amount of Support	3,480,731	3,661,000	4,114,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	20,500,718	21,560,000	24,233,000
Other Direct Research Costs*	4,069,995	4,280,000	4,811,000
Indirect Costs	4,286,942	4,508,000	5,067,000
TOTAL	$36,570,868	$38,460,000	$43,229,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

SCIENCE AND TECHNOLOGY CENTERS, BBS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$2,456,682	$2,901,000	$6,704,000
Applied Research	377,650	446,000	1,031,000
Development	0	0	0
Subtotal, Conduct of R&D	2,834,332	3,347,000	7,735,000
(Conduct of R&D Performed by Colleges and Universities.)	(3,005,000)	(3,548,000)	(8,200,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	1,315,668	1,553,000	3,590,000
Subtotal, R&D Facilities & Major Equipment	1,315,668	1,553,000	3,590,000
Total, Support of R&D	4,150,000	4,900,000	11,325,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$4,150,000	$4,900,000	$11,325,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	154	37	N/A
Dollars Requested (Total)	201,134	100,036	N/A
Action Summary			
Number of Awards	2	2	5
Dollars Obligated(Total)	4,150,000	4,900,000	11,325,000
Average Award Size	2,075,000	2,450,000	2,265,000
Average Award Duration(Years)	5.0	5.0	5.0
Dollar Distribution by Performer			
Universities	4,150,000	4,900,000	11,325,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	9	30	25
Amount of Scientist Support	319,040	377,000	871,000
Number of Years of Scientist Support	4	4	11
Postdoctoral Support			
Number of Postdoctorals Supported	14	19	38
Amount Postdoctoral Support	318,000	376,000	869,000
Graduate Students			
Number of Graduate Students Supported	13	17	35
Amount Graduate Student Support	167,400	198,000	457,000
Other Personnel Costs			
Amount of Support	520,257	614,000	1,420,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	1,315,668	1,553,000	3,590,000
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	576,993	681,000	1,574,000
Indirect Costs	932,642	1,101,000	2,544,000
TOTAL	$4,150,000	$4,900,000	$11,325,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$133,223,220	$148,810,000	$170,678,000
Applied Research	4,803,393	5,390,000	6,619,000
Development	0	0	0
Subtotal, Conduct of R&D	138,026,613	154,200,000	177,297,000
(Conduct of R&D Performed by Colleges and Universities.)	(127,482,779)	(141,363,837)	(159,988,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	2,508,019	2,836,000	2,824,000
Major Equipment	11,303,451	12,756,000	13,129,000
Subtotal, R&D Facilities & Major Equipment	13,811,470	15,592,000	15,953,000
Total, Support of R&D	151,838,083	169,792,000	193,250,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$151,838,083	$169,792,000	$193,250,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	2,785	2,952	3,295
Dollars Requested (Total)	909,588,146	1,001,033,436	$1,169,311,000
Action Summary			
Number of Awards	1,054	1,146	1,317
Dollars Obligated(Total)	151,838,083	169,792,000	193,250,000
Average Award Size	144,059	148,161	147,000
Dollar Distribution by Performer			
Universities	141,293,649	156,955,323	175,861,000
Industry	1,727,126	2,011,816	2,419,000
Federal Agencies	1,681,917	1,976,861	2,689,000
Other	7,135,391	8,848,000	12,281,000
Personnel			
Senior Scientists			
Number of Scientists Supported	1,065	1,153	1,320
Amount of Scientist Support	14,269,144	15,541,542	18,270,000
Number of Years of Scientist Support	236.6	259	299
Postdoctoral Support			
Number of Postdoctorals Supported	74	79	91
Amount Postdoctoral Support	1,229,087	1,344,734	1,620,000
Graduate Students			
Number of Graduate Students Supported	1,159	1,249	1,440
Amount Graduate Student Support	15,484,777	16,706,915	19,164,000
Other Personnel Costs			
Amount of Support	17,414,195	19,404,983	21,538,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	2,508,019	2,836,000	2,824,000
Major Equipment	10,403,451	11,759,000	11,714,000
Other Equipment and Instrumentation	18,394,428	20,901,099	24,534,000
Other Direct Research Costs*	42,905,879	48,990,749	56,416,000
Indirect Costs	29,229,102	32,306,978	37,170,000
TOTAL	$151,838,083	$169,792,000	$193,250,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, Fringe Benefits.

COMPUTER AND COMPUTATION RESEARCH

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$21,084,328	$21,893,000	$24,183,000
Applied Research	84,676	88,000	97,000
Development	0	0	0
Subtotal, Conduct of R&D	21,169,004	21,981,000	24,280,000
(Conduct of R&D Performed by Colleges and Universities.)	(21,067,079)	(21,875,000)	(24,163,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	21,169,004	21,981,000	24,280,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$21,169,004	$21,981,000	$24,280,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	929	965	1,066
Dollars Requested (Total)	$269,050,240	$279,370,320	$308,590,000
Action Summary			
Number of Awards	332	345	381
Dollars Obligated(Total)	21,169,004	21,981,000	24,280,000
Average Award Size	63,762	63,713	64,000
Average Award Duration(Years)	1.3	1.3	1.3
Dollar Distribution by Performer			
Universities	21,067,079	21,875,000	24,163,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	101,925	106,000	117,000
Personnel			
Senior Scientists			
Number of Scientists Supported	299	310	343
Amount of Scientist Support	4,306,898	4,472,000	4,940,000
Number of Years of Scientist Support	69	72	79
Postdoctoral Support			
Number of Postdoctorals Supported	12	12	14
Amount Postdoctoral Support	209,752	218,000	241,000
Graduate Students			
Number of Graduate Students Supported	385	400	442
Amount Graduate Student Support	5,205,485	5,405,000	5,970,000
Other Personnel Costs			
Amount of Support	2,085,110	2,165,000	2,392,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	456,109	474,000	523,000
Other Direct Research Costs*	3,110,272	3,230,000	3,567,000
Indirect Costs	5,795,378	6,017,000	6,647,000
TOTAL	$21,169,304	$21,981,000	$24,280,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

INFORMATION, ROBOTICS AND INTELLIGENT SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$18,295,273	$19,102,000	$21,875,000
Applied Research	840,827	878,000	1,005,000
Development	0	0	0
Subtotal, Conduct of R&D	19,136,100	19,980,000	22,880,000
(Conduct of R&D Performed by Colleges and Universities.)	(18,497,831)	(19,313,000)	(22,117,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	19,136,100	19,980,000	22,880,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$19,136,100	$19,980,000	$22,880,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	788	820	830
Dollars Requested (Total)	$199,409,061	$208,203,000	$238,423,000
Action Summary			
Number of Awards	288	300	320
Dollars Obligated(Total)	19,136,100	19,980,000	22,880,000
Average Award Size	66,445	66,600	72,000
Average Award Duration(Years)	2.5	2.5	2.5
Dollar Distribution by Performer			
Universities	18,497,831	19,313,000	22,117,000
Industry	223,542	233,500	267,000
Federal Agencies	26,720	28,500	32,000
Other	388,007	405,000	464,000
Personnel			
Senior Scientists			
Number of Scientists Supported	316	328	350
Amount of Scientist Support	3,655,820	3,818,200	4,371,000
Number of Years of Scientist Support	63	66	71
Postdoctoral Support			
Number of Postdoctorals Supported	41	43	48
Amount Postdoctoral Support	359,726	375,600	438,000
Graduate Students			
Number of Graduate Students Supported	311	325	370
Amount Graduate Student Support	3,705,546	3,869,000	4,432,000
Other Personnel Costs			
Amount of Support	2,959,214	3,089,700	3,538,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	725,506	757,500	867,000
Other Direct Research Costs*	1,634,482	1,706,000	1,954,000
Indirect Costs	6,095,806	6,364,000	7,280,000
TOTAL	$19,136,100	$19,980,000	$22,880,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

MICROELECTRONIC INFORMATION PROCESSING SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$12,838,710	$14,237,000	$16,175,000
Applied Research	2,138,746	2,372,000	2,695,000
Development	0	0	0
Subtotal, Conduct of R&D	14,977,456	16,609,000	18,870,000
(Conduct of R&D Performed by Colleges and Universities.)	(14,531,372)	(16,115,000)	(18,308,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	14,977,456	16,609,000	18,870,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$14,977,456	$16,609,000	$18,870,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	479	531	603
Dollars Requested (Total)	$95,087,937	$105,446,000	$119,801,000
Action Summary			
Number of Awards	182	202	229
Dollars Obligated(Total)	14,977,456	16,609,000	18,870,000
Average Award Size	82,294	82,223	82,000
Average Award Duration(Years)	3.8	3.8	3.8
Dollar Distribution by Performer			
Universities	14,531,372	16,115,000	18,308,000
Industry	127,434	141,000	161,000
Federal Agencies	318,650	353,000	401,000
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	197	218	248
Amount of Scientist Support	2,557,721	2,836,000	3,222,000
Number of Years of Scientist Support	38	42	48
Postdoctoral Support			
Number of Postdoctorals Supported	7	8	9
Amount Postdoctoral Support	104,726	117,000	132,000
Graduate Students			
Number of Graduate Students Supported	260	288	328
Amount Graduate Student Support	4,151,661	4,604,000	5,231,000
Other Personnel Costs			
Amount of Support	504,343	559,000	635,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	1,089,875	1,208,000	1,373,000
Other Direct Research Costs*	3,297,537	3,657,000	4,155,000
Indirect Costs	3,271,593	3,628,000	4,122,000
TOTAL	$14,977,456	$16,609,000	$18,870,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

ADVANCED SCIENTIFIC COMPUTING

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$42,666,063	$48,227,000	$48,034,000
Applied Research	7,500	8,000	8,000
Development	0	0	0
Subtotal, Conduct of R&D	42,673,563	48,235,000	48,042,000
(Conduct of R&D Performed by Colleges and Universities.)	($42,074,163)	($47,838,514)	($47,376,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	2,508,019	2,836,000	2,824,000
Major Equipment	10,403,451	11,759,000	11,714,000
Subtotal, R&D Facilities & Major Equipment	12,911,470	14,595,000	14,538,000
Total, Support of R&D	55,585,033	62,830,000	62,580,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$55,585,033	$62,830,000	$62,580,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	111	125	135
Dollars Requested (Total)	$109,455,000	$125,720,000	$123,247,000
Action Summary			
Number of Awards	45	51	56
Dollars Obligated(Total)	55,585,033	62,830,000	62,580,000
Average Award Size	1,235,223	1,231,961	1,118,000
Average Award Duration(Years)	2.0	2.0	2.0
Dollar Distribution by Performer			
Universities	54,985,033	62,153,000	61,914,000
Industry	600,000	677,000	666,000
Federal Agencies	0	0	0
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	40	45	48
Amount of Scientist Support	653,345	738,000	790,000
Number of Years of Scientist Support	9.6	11	11
Postdoctoral Support			
Number of Postdoctorals Supported	3	3	3
Amount Postdoctoral Support	105,747	120,000	119,000
Graduate Students			
Number of Graduate Students Supported	35	40	39
Amount Graduate Student Support	590,000	667,000	664,000
Other Personnel Costs			
Amount of Support	8,149,303	9,211,000	9,166,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	2,508,019	2,836,000	2,824,000
Major Equipment	10,403,451	11,759,000	11,714,000
Other Equipment and Instrumentation	5,973,911	6,752,000	6,727,000
Other Direct Research Costs*	20,204,817	22,838,000	22,698,000
Indirect Costs	6,996,439	7,909,000	7,878,000
TOTAL	$55,585,033	$62,830,000	$62,580,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

NETWORKING AND COMMUNICATIONS RESEARCH AND INFRASTRUCTURE

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$16,827,999	$21,207,000	$29,903,000
Applied Research	780,423	983,000	1,387,000
Development	0	0	0
Subtotal, Conduct of R&D	17,608,422	22,190,000	31,290,000
(Conduct of R&D Performed by Colleges and Universities.)	(9,846,619)	(12,409,000)	(17,497,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	17,608,422	22,190,000	31,290,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$17,608,422	$22,190,000	$31,290,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	237	299	421
Dollars Requested (Total)	$133,707,720	$168,498,000	$237,597,000
Action Summary			
Number of Awards	115	145	204
Dollars Obligated(Total)	17,608,422	22,190,000	31,290,000
Average Award Size	153,117	153,034	153,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	9,846,619	12,409,000	17,497,000
Industry	640,405	807,000	1,138,000
Federal Agencies	750,000	945,000	1,333,000
Other	6,371,398	8,029,000	11,322,000
Personnel			
Senior Scientists			
Number of Scientists Supported	85	107	151
Amount of Scientist Support	1,492,099	1,880,000	2,651,000
Number of Years of Scientist Support	30	38	53
Postdoctoral Support			
Number of Postdoctorals Supported	4	5	7
Amount Postdoctoral Support	92,743	117,000	165,000
Graduate Students			
Number of Graduate Students Supported	72	91	128
Amount Graduate Student Support	758,317	956,000	1,348,000
Other Personnel Costs			
Amount of Support	1,505,038	1,897,000	2,674,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,212,436	2,788,000	3,932,000
Other Direct Research Costs*	8,238,692	10,382,000	14,640,000
Indirect Costs	3,309,095	4,170,000	5,880,000
TOTAL	$17,608,422	$22,190,000	$31,290,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

CROSS-DISCIPLINARY ACTIVITIES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$17,078,599	$19,232,000	$23,536,000
Applied Research	358,750	404,000	494,000
Development	0	0	0
Subtotal, Conduct of R&D	17,437,349	19,636,000	24,030,000
(Conduct of R&D Performed by Colleges and Universities.)	(17,027,543)	(19,175,000)	(23,465,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	17,437,349	19,636,000	24,030,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$17,437,349	$19,636,000	$24,030,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	174	196	240
Dollars Requested (Total)	$102,790,739	$115,752,000	$141,653,000
Action Summary			
Number of Awards	90	101	124
Dollars Obligated(Total)	17,437,349	19,636,000	24,030,000
Average Award Size	193,748	194,416	194,000
Average Award Duration(Years)	2.1	2.1	2.1
Dollar Distribution by Performer			
Universities	17,027,543	19,175,000	23,465,000
Industry	135,745	153,000	187,000
Federal Agencies	0	0	0
Other	274,061	308,000	378,000
Personnel			
Senior Scientists			
Number of Scientists Supported	115	130	158
Amount of Scientist Support	1,158,261	1,304,000	1,596,000
Number of Years of Scientist Support	27	30	37
Postdoctoral Support			
Number of Postdoctorals Supported	7	8	10
Amount Postdoctoral Support	144,724	163,000	199,000
Graduate Students			
Number of Graduate Students Supported	75	84	103
Amount Graduate Student Support	873,679	984,000	1,204,000
Other Personnel Costs			
Amount of Support	1,773,858	1,998,000	2,445,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	7,036,591	7,924,000	9,697,000
Other Direct Research Costs*	3,568,199	4,018,000	4,917,000
Indirect Costs	2,882,037	3,245,000	3,972,000
TOTAL	$17,437,349	$19,636,000	$24,030,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

SCIENCE AND TECHNOLOGY CENTERS, CISE

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$4,432,248	$4,912,000	$6,972,000
Applied Research	592,471	657,000	953,000
Development	0	0	0
Subtotal, Conduct of R&D	5,024,719	5,569,000	7,905,000
(Conduct of R&D Performed by Colleges and Universities.)	(4,438,172)	(4,919,000)	(6,982,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	900,000	997,000	1,415,000
Subtotal, R&D Facilities & Major Equipment	900,000	997,000	1,415,000
Total, Support of R&D	5,924,719	6,566,000	9,320,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$5,924,719	$6,566,000	$9,320,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	67	16	N/A
Dollars Requested (Total)	87,449	43,934	N/A
Action Summary			
Number of Awards	2	2	3
Dollars Obligated(Total)	5,924,719	6,566,000	9,320,000
Average Award Size	2,962,360	3,283,000	3,107,000
Average Award Duration(Years)	5.0	5.0	5.0
Dollar Distribution by Performer			
Universities	5,338,172	5,916,000	8,397,000
Industry	0	0	0
Federal Agencies	586,547	650,000	923,000
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	15	15	21
Amount of Scientist Support	445,000	493,000	700,000
Number of Years of Scientist Support	0.0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	211,667	235,000	334,000
Graduate Students			
Number of Graduate Students Supported	21	21	30
Amount Graduate Student Support	280,000	222,000	315,000
Other Personnel Costs			
Amount of Support	437,329	485,000	688,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	900,000	997,000	1,415,000
Other Direct Research Costs*	2,851,000	3,160,000	4,405,000
Indirect Costs	878,754	974,000	1,385,000
TOTAL	$5,924,719	$6,566,000	$9,320,000

*Includes: Supplies, Publications, Consultants. Computer Services, Subcontracts, Travel.

ENGINEERING

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$141,921,539	$150,780,001	$170,405,000
Applied Research	45,143,204	49,440,999	55,595,000
Development	0	0	0
Subtotal, Conduct of R&D	187,064,743	200,221,000	226,000,000
(Conduct of R&D Performed by Colleges and Universities.)	(181,733,187)	(194,142,000)	(219,889,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	187,064,743	200,221,000	226,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$187,064,743	$200,221,000	$226,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	5,636	6,079	6,697
Dollars Requested (Total)	$2,266,084,406	$2,411,766,264	$2,704,418,000
Action Summary			
Number of Awards	2,387	2,415	2,630
Dollars Obligated(Total)	187,064,743	200,221,000	226,000,000
Average Award Size	78,385	82,907	86,000
Dollar Distribution by Performer			
Universities	181,733,187	194,142,000	219,889,000
Industry	2,348,983	2,684,000	2,611,000
Federal Agencies	138,139	138,000	143,000
Other	2,844,434	3,257,000	3,357,000
Personnel			
Senior Scientists			
Number of Scientists Supported	2,986	3,196	3,685
Amount of Scientist Support	29,183,197	31,405,700	36,305,000
Number of Years of Scientist Support	516	556	638
Postdoctoral Support			
Number of Postdoctorals Supported	214	221	244
Amount Postdoctoral Support	3,565,223	3,703,500	4,055,000
Graduate Students			
Number of Graduate Students Supported	3,190	3,375	3,772
Amount Graduate Student Support	36,985,699	39,883,000	45,330,000
Other Personnel Costs			
Amount of Support	17,205,272	18,699,600	21,323,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	21,643,747	22,653,700	25,329,000
Other Direct Research Costs*	37,190,147	40,346,000	45,363,000
Indirect Costs	41,291,458	43,529,500	48,295,000
TOTAL	$187,064,743	$200,221,000	$226,000,000

*Includes: Supplies, Publications, Consultant, Computer Subcontracts, Travel.

BIOLOGICAL AND CRITICAL SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$25,826,991	$26,473,000	$27,391,000
Applied Research	8,239,986	9,127,000	8,739,000
Development	0	0	0
Subtotal, Conduct of R&D	34,066,977	35,600,000	36,130,000
(Conduct of R&D Performed by Colleges and Universities)	(31,384,520)	(32,276,000)	(33,200,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	34,066,977	35,600,000	36,130,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$34,066,977	$35,600,000	$36,130,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	922	1,100	1,000
Dollars Requested (Total)	$239,349,402	$255,000,000	$253,844,000
Action Summary			
Number of Awards	471	490	495
Dollars Obligated (Total)	34,066,977	35,600,000	36,130,000
Average Award Size	72,000	73,000	73,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	31,384,520	32,276,000	33,200,000
Industry	1,606,452	1,884,000	1,704,000
Federal Agencies	73,872	73,000	78,000
Other	1,002,133	1,367,000	1,148,000
Personnel			
Senior Scientists			
Number of Scientists Supported	587	613	622
Amount of Scientist Support	4,860,295	5,000,000	5,155,000
Number of Years of Scientist Support	102	107	108
Postdoctoral Support			
Number of Postdoctorals Supported	41	43	44
Amount Postdoctoral Support	703,769	735,000	746,000
Graduate Students			
Number of Graduate Students Supported	471	492	499
Amount Graduate Student Support	5,250,817	5,405,000	5,577,000
Other Personnel Costs			
Amount of Support	2,637,220	2,756,000	2,797,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,069,022	2,141,000	2,173,000
Other Direct Research Costs*	11,485,572	11,917,000	12,094,000
Indirect Costs	7,154,204	7,476,000	7,588,000
TOTAL	$34,066,977	$35,600,000	$36,130,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

CHEMICAL AND THERMAL SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$25,037,369	$24,784,000	$26,784,000
Applied Research	5,941,420	5,881,000	6,356,000
Development	0	0	0
Subtotal, Conduct of R&D	30,978,789	30,665,000	33,140,000
(Conduct of R&D Performed by Colleges and Universities.)	(30,695,647)	(30,385,000)	(32,840,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	30,978,789	30,665,000	33,140,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$30,978,789	$30,665,000	$33,140,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,189	1,177	1,272
Dollars Requested (Total)	$265,693,600	$263,002,348	$284,230,000
Action Summary			
Number of Awards	506	495	535
Dollars Obligated(Total)	30,978,789	30,665,000	33,140,000
Average Award Size	61,000	62,000	62,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	30,695,647	30,385,000	32,840,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	283,142	280,000	300,000
Personnel			
Senior Scientists			
Number of Scientists Supported	459	455	491
Amount of Scientist Support	4,411,951	4,367,000	4,720,000
Number of Years of Scientist Support	45	44	48
Postdoctoral Support			
Number of Postdoctorals Supported	46	45	49
Amount Postdoctoral Support	800,613	793,000	856,000
Graduate Students			
Number of Graduate Students Supported	592	586	633
Amount Graduate Student Support	7,692,591	7,615,000	8,229,000
Other Personnel Costs			
Amount of Support	2,412,944	2,389,000	2,581,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	4,409,037	4,364,000	4,717,000
Other Direct Research Costs*	4,290,853	4,247,000	4,590,000
Indirect Costs	6,960,800	6,890,000	7,447,000
TOTAL	$30,978,789	$30,665,000	$33,140,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

ELECTRICAL AND COMMUNICATIONS SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$23,815,267	$23,686,000	$25,360,000
Applied Research	6,057,159	6,024,000	6,450,000
Development	0	0	0
Subtotal, Conduct of R&D	29,872,426	29,710,000	31,810,000
(Conduct of R&D Performed by Colleges and Universities.)	(29,521,939)	(29,361,000)	(31,437,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	29,872,426	29,710,000	31,810,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$29,872,426	$29,710,000	$31,810,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,039	1,033	1,106
Dollars Requested (Total)	$554,685,844	$551,669,858	$590,664,000
Action Summary			
Number of Awards	472	465	490
Dollars Obligated(Total)	29,872,426	29,710,000	31,810,000
Average Award Size	63,000	64,000	65,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	29,521,939	29,361,000	31,437,000
Industry	283,557	282,000	302,000
Federal Agencies	0	0	0
Other	66,930	67,000	71,000
Personnel			
Senior Scientists			
Number of Scientists Supported	511	509	545
Amount of Scientist Support	4,797,070	4,771,000	5,108,000
Number of Years of Scientist Support	93	93	99
Postdoctoral Support			
Number of Postdoctorals Supported	47	46	50
Amount Postdoctoral Support	721,269	717,000	768,000
Graduate Students			
Number of Graduate Students Supported	553	550	589
Amount Graduate Student Support	6,297,333	6,263,000	6,706,000
Other Personnel Costs			
Amount of Support	2,696,414	2,682,000	2,871,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	3,352,144	3,334,000	3,570,000
Other Direct Research Costs*	4,798,365	4,772,000	5,110,000
Indirect Costs	7,209,831	7,171,000	7,677,000
TOTAL	$29,872,426	$29,710,000	$31,810,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MECHANICAL AND STRUCTURAL SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$18,978,331	$18,700,001	$20,108,000
Applied Research	4,060,022	3,999,999	4,302,000
Development	0	0	0
Subtotal,Conduct of R&D	23,038,353	22,700,000	24,410,000
(Conduct of R&D Performed by Colleges and Universities.)	(22,762,298)	(22,428,000)	(24,118,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	23,038,353	22,700,000	24,410,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$23,038,353	$22,700,000	$24,410,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,202	1,184	1,274
Dollars Requested (Total)	$246,041,062	$242,427,578	$260,690,000
Action Summary			
Number of Awards	410	400	430
Dollars Obligated(Total)	23,038,353	22,700,000	24,410,000
Average Award Size	56,000	57,000	57,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	22,762,298	22,428,000	24,118,000
Industry	67,812	67,000	71,000
Federal Agencies	0	0	0
Other	208,243	205,000	221,000
Personnel			
Senior Scientists			
Number of Scientists Supported	440	434	466
Amount of Scientist Support	4,343,377	4,280,000	4,602,000
Number of Years of Scientist Support	77	76	82
Postdoctoral Support			
Number of Postdoctorals Supported	32	32	34
Amount Postdoctoral Support	410,282	404,000	435,000
Graduate Students			
Number of Graduate Students Supported	462	455	490
Amount Graduate Student Support	5,340,330	5,262,000	5,658,000
Other Personnel Costs			
Amount of Support	2,115,311	2,084,000	2,241,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,659,932	2,621,000	2,818,000
Other Direct Research Costs*	3,094,351	3,049,000	3,279,000
Indirect Costs	5,074,770	5,000,000	5,377,000
TOTAL	$23,038,353	$22,700,000	$24,410,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

DESIGN AND MANUFACTURING SYSTEMS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$15,312,640	$15,511,000	$16,766,000
Applied Research	2,743,348	2,779,000	3,004,000
Development	0	0	0
Subtotal, Conduct of R&D	18,055,988	18,290,000	19,770,000
(Conduct of R&D Performed by Colleges and Universities)	(17,270,682)	(17,495,000)	(18,910,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	18,055,988	18,290,000	19,770,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$18,055,988	$18,290,000	$19,770,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	656	665	718
Dollars Requested (Total)	$193,616,155	$196,125,489	$211,996,000
Action Summary			
Number of Awards	270	270	290
Dollars Obligated (Total)	18,055,988	18,290,000	19,770,000
Average Award Size	67,000	68,000	68,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	17,270,682	17,495,000	18,910,000
Industry	50,520	51,000	55,000
Federal Agencies	0	0	0
Other	734,786	744,000	805,000
Personnel			
Senior Scientists			
Number of Scientists Supported	364	369	399
Amount of Scientist Support	3,636,534	3,684,000	3,982,000
Number of Years of Scientist Support	63	64	69
Postdoctoral Support			
Number of Postdoctorals Supported	13	13	14
Amount Postdoctoral Support	253,287	257,000	277,000
Graduate Students			
Number of Graduate Students Supported	394	399	431
Amount Graduate Student Support	4,417,057	4,474,000	4,836,000
Other Personnel Costs			
Amount of Support	1,683,527	1,705,000	1,843,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	1,158,355	1,173,000	1,268,000
Other Direct Research Costs*	2,914,797	2,953,000	3,191,000
Indirect Costs	3,992,431	4,044,000	4,373,000
TOTAL	$18,055,988	$18,290,000	$19,770,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

ENGINEERING CENTERS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$24,256,389	$27,861,000	$33,186,000
Applied Research	16,170,926	18,574,000	22,124,000
Development	0	0	0
Subtotal, Conduct of R&D	40,427,315	46,435,000	55,310,000
(Conduct of R&D Performed by Colleges and Universities.)	(40,214,691)	(46,191,000)	(55,019,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	40,427,315	46,435,000	55,310,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$40,427,315	$46,435,000	$55,310,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	172	198	235
Dollars Requested (Total)	$713,983,972	$820,085,275	$976,826,000
Action Summary			
Number of Awards	105	110	120
Dollars Obligated(Total)	40,427,315	46,435,000	55,310,000
Average Award Size	385,000	422,000	461,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	40,214,691	46,191,000	55,019,000
Industry	130,571	150,000	179,000
Federal Agencies	0	0	0
Other	82,053	94,000	112,000
Personnel			
Senior Scientists			
Number of Scientists Supported	484	556	662
Amount of Scientist Support	5,988,771	6,878,700	8,193,000
Number of Years of Scientist Support	117	134	160
Postdoctoral Support			
Number of Postdoctorals Supported	30	34	41
Amount Postdoctoral Support	630,736	724,500	863,000
Graduate Students			
Number of Graduate Students Supported	625	718	855
Amount Graduate Student Support	6,690,759	7,685,000	9,154,000
Other Personnel Costs			
Amount of Support	4,531,198	5,204,600	6,149,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	4,626,239	5,313,700	6,679,000
Other Direct Research Costs*	8,204,701	9,424,000	11,076,000
Indirect Costs	9,754,911	11,204,500	13,196,000
TOTAL	$40,427,315	$46,435,000	$55,310,000

*Includes: Supplies, Publications, Consultants, Computer Subcontracts, Travel.

ENGINEERING INFRASTRUCTURE DEVELOPMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$8,694,552	$13,760,000	$20,810,000
Applied Research	1,930,343	3,061,000	4,620,000
Development	0	0	0
Subtotal,Conduct of R&D	10,624,895	16,821,000	25,430,000
(Conduct of R&D Performed by Colleges and Universities.)	(9,963,410)	(16,006,000)	(24,365,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	10,624,895	16,821,000	25,430,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$10,624,895	$16,821,000	$25,430,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	656	722	1,091
Dollars Requested (Total)	$52,714,371	$83,655,736	$136,160,000
Action Summary			
Number of Awards	153	185	270
Dollars Obligated(Total)	10,624,895	16,821,000	25,430,000
Average Award Size	69,000	91,000	94,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	9,963,410	16,006,000	24,365,000
Industry	210,071	250,000	300,000
Federal Agencies	64,267	65,000	65,000
Other	387,147	500,000	700,000
Personnel			
Senior Scientists			
Number of Scientists Supported	140	260	500
Amount of Scientist Support	1,563,281	2,343,000	4,545,000
Number of Years of Scientist Support	19	38	72
Postdoctoral Support			
Number of Postdoctorals Supported	5	8	12
Amount Postdoctoral Support	65,367	73,000	110,000
Graduate Students			
Number of Graduate Students Supported	96	175	275
Amount Graduate Student Support	1,388,812	3,089,000	5,170,000
Other Personnel Costs			
Amount of Support	1,120,666	1,879,000	2,841,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	3,309,016	3,707,000	4,104,000
Other Direct Research Costs*	2,483,508	3,986,000	6,023,000
Indirect Costs	1,144,431	1,744,000	2,637,000
TOTAL	$10,624,895	$16,821,000	$25,430,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

GEOSCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$303,093,853	$317,856,887	$375,102,000
Applied Research	3,360,671	3,501,114	4,414,000
Development	0	0	0
Subtotal, Conduct of R&D	306,454,524	321,358,001	379,516,000
(Conduct of R&D Performed by Colleges and Universities.)	(215,713,421)	(226,474,893)	(269,361,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	202,000	213,312	246,000
Major Equipment	3,252,552	3,434,687	3,963,000
Subtotal, R&D Facilities & Major Equipment	3,454,552	3,647,999	4,209,000
Total, Support of R&D	309,909,076	325,006,000	383,725,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$309,909,076	$325,006,000	$383,725,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	4,184	4,288	4,719
Dollars Requested (Total)	895,263,511	934,323,193	$1,057,566,000
Action Summary			
Number of Awards	2,403	2,560	2,915
Dollars Obligated(Total)	309,909,076	325,006,000	383,725,000
Average Award Size	128,964	127,000	132,000
Dollar Distribution by Performer			
Universities	215,713,021	226,474,892	269,361,000
Industry	1,935,048	2,036,840	2,372,000
Federal Agencies	1,413,137	1,554,585	1,922,700
Other	90,847,870	94,939,683	110,069,300
Personnel			
Senior Scientists			
Number of Scientists Supported	2,761	2,930	3,357
Amount of Scientist Support	36,988,013	39,237,417	46,011,000
Number of Years of Scientist Support	658	700	803
Postdoctoral Support			
Number of Postdoctorals Supported	342	374	433
Amount Postdoctoral Support	5,630,858	6,030,464	6,971,000
Graduate Students			
Number of Graduate Students Supported	1,666	1,855	2,035
Amount Graduate Student Support	16,991,243	18,392,408	21,523,000
Other Personnel Costs			
Amount of Support	70,835,048	73,498,935	86,018,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	202,000	213,312	246,000
Major Equipment	3,252,552	3,434,687	3,963,000
Other Equipment and Instrumentation	23,229,576	24,531,043	31,040,000
Other Direct Research Costs*	98,495,380	102,449,285	120,018,000
Indirect Costs	54,284,406	57,218,449	67,935,000
TOTAL	$309,909,076	$325,006,000	$383,725,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, Fringe Benefits.

ATMOSPHERIC SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$94,120,677	$99,391,413	$114,690,000
Applied Research	1,001,506	1,057,588	1,220,000
Development	0	0	0
Subtotal, Conduct of R&D	95,122,183	100,449,001	115,910,000
(Conduct of R&D Performed by Colleges and Universities.)	(46,968,891)	(49,599,455)	(57,234,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	202,000	213,312	246,000
Major Equipment	3,252,552	3,434,687	3,963,000
Subtotal, R&D Facilities & Major Equipment	3,454,552	3,647,999	4,209,000
Total, Support of R&D	98,576,735	104,097,000	120,119,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$98,576,735	$104,097,000	$120,119,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	866	893	1,031
Dollars Requested (Total)	$216,716,328	$228,051,907	$264,075,000
Action Summary			
Number of Awards	600	634	731
Dollars Obligated(Total)	98,576,735	104,097,000	120,119,000
Average Award Size	164,295	164,000	164,000
Average Award Duration (Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	46,968,891	49,599,455	57,234,000
Industry	1,297,581	1,370,242	1,581,000
Federal Agencies	304,650	321,498	371,000
Other	50,005,613	52,805,805	60,933,000
Personnel			
Senior Scientists			
Number of Scientists Supported	961	994	1,167
Amount of Scientist Support	17,250,944	18,216,975	21,021,000
Number of Years of Scientist Support	314	332	383
Postdoctoral Support			
Number of Postdoctorals Supported	128	135	156
Amount Postdoctoral Support	2,365,846	2,498,328	2,883,000
Graduate Students			
Number of Graduate Students Supported	516	547	631
Amount Graduate Student Support	5,520,308	5,829,432	6,727,000
Other Personnel Costs			
Amount of Support	26,615,772	28,106,190	32,432,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	202,000	213,312	246,000
Major Equipment	3,252,552	3,434,687	3,963,000
Other Equipment and Instrumentation	5,827,436	5,308,967	6,126,000
Other Direct Research Costs*	22,065,298	24,145,900	27,862,000
Indirect Costs	15,476,579	16,343,229	18,859,000
TOTAL	$98,576,735	$104,097,000	$120,119,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

EARTH SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$53,720,719	$59,559,692	$70,870,000
Applied Research	501,165	546,308	661,000
Development	0	0	0
Subtotal, Conduct of R&D	54,221,884	60,106,000	71,531,000
(Conduct of R&D Performed by Colleges and Universities.)	(46,179,442)	(51,139,123)	(60,921,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	54,221,884	60,106,000	71,531,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$54,221,884	$60,106,000	$71,531,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,687	1,770	1,800
Dollars Requested (Total)	$243,691,688	$260,000,000	$270,000,000
Action Summary			
Number of Awards	816	910	990
Dollars Obligated(Total)	54,221,884	60,106,000	71,531,000
Average Award Size	66,000	66,000	72,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	46,179,442	51,139,123	60,921,000
Industry	243,100	264,997	321,000
Federal Agencies	6,162	6,717	7,700
Other	7,793,180	8,695,163	10,281,300
Personnel			
Senior Scientists			
Number of Scientists Supported	751	830	900
Amount of Scientist Support	6,289,544	7,056,083	8,297,000
Number of Years of Scientist Support	61	75	73
Postdoctoral Support			
Number of Postdoctorals Supported	85	106	120
Amount Postdoctoral Support	1,185,951	1,392,777	1,564,000
Graduate Students			
Number of Graduate Students Supported	635	773	763
Amount Graduate Student Support	6,671,454	7,572,395	8,801,000
Other Personnel Costs			
Amount of Support	5,119,496	5,580,642	6,754,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	9,066,200	9,882,852	13,960,000
Other Direct Research Costs*	14,162,119	15,537,793	16,684,000
Indirect Costs	11,727,120	13,083,458	15,471,000
TOTAL	$54,221,884	$60,106,000	$71,531,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

OCEAN SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$144,282,995	$145,675,841	$169,031,000
Applied Research	1,600,000	1,697,159	1,969,000
Development	0	0	0
Subtotal, Conduct of R&D	145,882,995	147,373,000	171,000,000
(Conduct of R&D Performed by Colleges and Universities.)	(112,175,026)	(113,320,748)	(131,488,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	145,882,995	147,373,000	171,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$145,882,995	$147,373,000	$171,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,445	1,460	1,696
Dollars Requested (Total)	$403,646,581	$407,769,306	$473,143,000
Action Summary			
Number of Awards	858	867	1,006
Dollars Obligated (Total)	145,882,995	147,373,000	171,000,000
Average Award Size	170,027	169,980	170,000
Average Award Duration (Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	112,175,026	113,320,747	131,488,000
Industry	378,367	382,232	444,000
Federal Agencies	540,525	546,046	634,000
Other	32,789,077	33,123,975	38,434,000
Personnel			
Senior Scientists			
Number of Scientists Supported	971	981	1,138
Amount of Scientist Support	12,346,505	12,472,608	14,472,000
Number of Years of Scientist Support	263	266	308
Postdoctoral Support			
Number of Postdoctorals Supported	116	117	136
Amount Postdoctoral Support	1,884,061	1,903,304	2,208,000
Graduate Students			
Number of Graduate Students Supported	451	456	529
Amount Graduate Student Support	4,296,481	4,340,364	5,036,000
Other Personnel Costs			
Amount of Support	37,672,780	38,057,558	44,159,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	8,586,952	8,674,657	10,065,000
Other Direct Research Costs*	56,405,509	56,981,619	66,118,000
Indirect Costs	24,690,707	24,942,890	28,942,000
TOTAL	$145,882,995	$147,373,000	$171,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

ARCTIC RESEARCH

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$10,196,462	$12,343,472	$16,508,000
Applied Research	88,000	106,528	142,000
Development	0	0	0
Subtotal, Conduct of R&D	10,284,462	12,450,000	16,650,000
(Conduct of R&D Performed by Colleges and Universities.)	(9,446,462)	(11,435,567)	(15,293,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	10,284,462	12,450,000	16,650,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$10,284,462	$12,450,000	$16,650,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	120	145	194
Dollars Requested (Total)	$31,100,000	$37,647,810	$50,348,000
Action Summary			
Number of Awards	128	148	185
Dollars Obligated(Total)	10,284,462	12,450,000	16,650,000
Average Award Size	80,347	84,122	90,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	9,446,462	11,435,567	15,293,000
Industry	16,000	19,369	26,000
Federal Agencies	562,000	680,324	910,000
Other	260,000	314,740	421,000
Personnel			
Senior Scientists			
Number of Scientists Supported	94	114	152
Amount of Scientist Support	1,001,000	1,211,751	1,621,000
Number of Years of Scientist Support	18	22	29
Postdoctoral Support			
Number of Postdoctorals Supported	13	16	21
Amount Postdoctoral Support	195,000	236,055	316,000
Graduate Students			
Number of Graduate Students Supported	57	69	92
Amount Graduate Student Support	438,000	530,217	709,000
Other Personnel Costs			
Amount of Support	1,342,000	1,624,545	2,173,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	549,000	664,587	889,000
Other Direct Research Costs*	4,627,462	5,601,973	7,490,000
Indirect Costs	2,132,000	2,580,872	3,452,000
TOTAL	$10,284,462	$12,450,000	$16,650,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

SCIENCE AND TECHNOLOGY CENTERS, GEO

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$853,000	$886,469	$4,003,000
Applied Research	90,000	93,531	422,000
Development	0	0	0
Subtotal, Conduct of R&D	943,000	980,000	4,425,000
(Conduct of R&D Performed by Colleges and Universities.)	(943,000)	(980,000)	(4,425,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	943,000	980,000	4,425,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$943,000	$980,000	$4,425,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	86	20	N/A
Dollars Requested (Total)	108,914	54,170	N/A
Action Summary			
Number of Awards	1	1	3
Dollars Obligated(Total)	943,000	980,000	4,425,000
Average Award Size	943,000	980,000	1,475,000
Average Award Duration(Years)	52.0	52.0	52.0
Dollar Distribution by Performer			
Universities	943,000	980,000	4,425,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	4	11	20
Amount of Scientist Support	100,000	280,000	600,000
Number of Years of Scientist Support	2	5	10
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	5	10	20
Amount Graduate Student Support	65,000	120,000	250,000
Other Personnel Costs			
Amount of Support	85,000	130,000	500,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	435,000	182,000	1,864,000
Indirect Costs	258,000	268,000	1,211,000
TOTAL	$943,000	$980,000	$4,425,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MATHEMATICAL AND PHYSICAL SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$474,252,007	$487,479,300	$524,495,000
Applied Research	12,124,294	10,303,700	11,712,000
Development	0	0	0
Subtotal, Conduct of R&D	486,376,301	497,783,000	536,207,000
(Conduct of R&D Performed by Colleges and Universities.)	(425,490,792)	(436,324,000)	(471,709,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	1,600,000	4,799,000	44,800,000
Major Equipment	17,826,993	54,424,000	40,493,000
Subtotal, R&D Facilities & Major Equipment	19,426,993	59,223,000	85,293,000
Total, Support of R&D	503,803,294	557,006,000	621,500,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$503,803,294	$557,006,000	$621,500,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	8,376	8,371	8,770
Dollars Requested (Total)	$2,162,179,037	$2,263,014,883	$2,035,068,000
Action Summary			
Number of Awards	4,335	4,392	4,541
Dollars Obligated(Total)	503,803,294	557,006,000	621,500,000
Average Award Size	116,218	127,000	137,000
Dollar Distribution by Performer			
Universities	430,578,876	446,490,000	535,934,000
Industry	570,868	542,500	380,000
Federal Agencies	1,758,818	1,766,000	1,866,000
Other	70,894,734	108,207,500	83,120,000
Personnel			
Senior Scientists			
Number of Scientists Supported	5,080	5,150	5,395
Amount of Scientist Support	57,230,031	59,030,000	62,724,000
Number of Years of Scientist Support	995	1,018	1,053
Postdoctoral Support			
Number of Postdoctorals Supported	1,886	1,928	2,063
Amount Postdoctoral Support	36,046,683	36,710,000	39,362,000
Graduate Students			
Number of Graduate Students Supported	5,304	5,388	5,665
Amount Graduate Student Support	53,836,276	54,994,000	58,682,000
Other Personnel Costs			
Amount of Support	66,010,160	67,875,000	71,981,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	1,600,000	4,799,000	44,800,000
Major Equipment	17,826,993	54,424,000	40,493,000
Other Equipment and Instrumentation	67,541,003	71,081,000	77,536,000
Other Direct Research Costs*	90,543,100	92,522,000	102,322,000
Indirect Costs	113,149,048	115,571,000	123,600,000
TOTAL	$503,803,294	$557,006,000	$621,500,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MATHEMATICAL SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$65,943,442	$69,039,500	$73,636,000
Applied Research	75,000	78,500	84,000
Development	0	0	0
Subtotal, Conduct of R&D	66,018,442	69,118,000	73,720,000
(Conduct of R&D Performed by Colleges and Universities.)	(58,654,278)	(61,679,000)	(66,080,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	66,018,442	69,118,000	73,720,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$66,018,442	$69,118,000	$73,720,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	2,760	2,900	3,100
Dollars Requested (Total)	$300,775,511	$325,000,000	$360,000,000
Action Summary			
Number of Awards	1,345	1,360	1,365
Dollars Obligated(Total)	66,018,442	69,118,000	73,720,000
Average Award Size	49,084	50,820	54,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	58,654,278	61,679,000	66,080,000
Industry	58,155	20,000	20,000
Federal Agencies	41,000	20,000	20,000
Other	7,265,009	7,399,000	7,600,000
Personnel			
Senior Scientists			
Number of Scientists Supported	1,406	1,400	1,400
Amount of Scientist Support	18,032,622	19,020,000	20,420,000
Number of Years of Scientist Support	262	250	260
Postdoctoral Support			
Number of Postdoctorals Supported	278	280	280
Amount Postdoctoral Support	5,810,527	6,000,000	6,400,000
Graduate Students			
Number of Graduate Students Supported	925	950	950
Amount Graduate Student Support	6,196,561	6,599,000	7,100,000
Other Personnel Costs			
Amount of Support	5,739,163	5,999,000	6,400,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,483,402	2,500,000	2,700,000
Other Direct Research Costs*	9,590,970	10,000,000	10,500,000
Indirect Costs	18,165,197	19,000,000	20,200,000
TOTAL	$66,018,442	$69,118,000	$73,720,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

ASTRONOMICAL SCIENCES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$76,474,228	$79,699,000	$86,700,000
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	76,474,228	79,699,000	86,700,000
(Conduct of R&D Performed by Colleges and Universities.)	(27,415,100)	(29,175,000)	(31,587,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	1,600,000	2,499,000	800,000
Major Equipment	11,150,000	9,449,000	15,200,000
Subtotal, R&D Facilities & Major Equipment	12,750,000	11,948,000	16,000,000
Total, Support of R&D	89,224,228	91,647,000	100,700,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$89,224,228	$91,647,000	$100,700,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	512	525	540
Dollars Requested (Total)	$267,790,026	$225,000,000	$240,000,000
Action Summary			
Number of Awards	330	335	340
Dollars Obligated(Total)	89,224,228	91,647,000	100,700,000
Average Award Size	270,376	274,000	296,000
Dollar Distribution by Performer			
Universities	28,365,100	30,124,000	31,587,000
Industry	204,000	209,500	230,000
Federal Agencies	82,000	85,000	95,000
Other	60,573,128	61,228,500	68,790,000
Personnel			
Senior Scientists			
Number of Scientists Supported	473	473	473
Amount of Scientist Support	9,456,178	9,835,000	10,350,000
Number of Years of Scientist Support	192	192	192
Postdoctoral Support			
Number of Postdoctorals Supported	95	95	95
Amount Postdoctoral Support	1,794,249	1,865,000	2,000,000
Graduate Students			
Number of Graduate Students Supported	260	260	265
Amount Graduate Student Support	2,789,812	2,900,000	3,100,000
Other Personnel Costs			
Amount of Support	27,855,921	28,975,000	30,500,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	1,600,000	2,499,000	800,000
Major Equipment*	11,150,000	9,449,000	15,200,000
Other Equipment and Instrumentation**	7,422,000	8,100,000	9,175,000
Other Direct Research Costs***	18,963,489	19,500,000	20,575,000
Indirect Costs	8,192,579	8,524,000	9,000,000
TOTAL	$89,224,228	$91,647,000	$100,700,000

*Includes salaries, supplies, and other costs for constructed equipment.
**Does not include salaries, supplies, and other costs for constructed equipment.
***Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

PHYSICS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$117,365,036	$120,887,800	$127,186,000
Applied Research	1,918,954	1,943,200	2,044,000
Development	0	0	0
Subtotal, Conduct of R&D	119,283,990	122,831,000	129,230,000
(Conduct of R&D Performed by Colleges and Universities.)	(119,199,000)	(121,745,000)	(128,029,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	3,000,000	1,000,000	1,000,000
Subtotal, R&D Facilities & Major Equipment	3,000,000	1,000,000	1,000,000
Total, Support of R&D	122,283,990	123,831,000	130,230,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$122,283,990	$123,831,000	$130,230,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	826	836	880
Dollars Requested (Total)	$388,971,778	$393,892,645	$414,247,000
Action Summary			
Number of Awards	630	638	655
Dollars Obligated(Total)	122,283,990	123,831,000	130,230,000
Average Award Size	194,102	194,000	199,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	121,155,991	122,689,000	129,029,000
Industry	11	0	0
Federal Agencies	112,000	113,000	119,000
Other	1,015,988	1,029,000	1,082,000
Personnel			
Senior Scientists			
Number of Scientists Supported	938	950	970
Amount of Scientist Support	11,449,908	11,395,000	11,694,000
Number of Years of Scientist Support	223	226	237
Postdoctoral Support			
Number of Postdoctorals Supported	446	452	475
Amount Postdoctoral Support	9,580,884	9,702,000	10,203,000
Graduate Students			
Number of Graduate Students Supported	965	957	1,006
Amount Graduate Student Support	9,779,894	9,904,000	10,415,000
Other Personnel Costs			
Amount of Support	11,657,820	11,805,000	11,915,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	3,000,000	1,000,000	1,000,000
Other Equipment and Instrumentation	24,032,300	26,374,000	28,780,000
Other Direct Research Costs*	22,737,980	23,026,000	24,216,000
Indirect Costs	30,045,203	30,425,000	31,998,000
TOTAL	$122,283,990	$123,831,000	$130,230,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontractors, Travel.

CHEMISTRY

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$95,321,965	$96,504,000	$101,830,000
Applied Research	1,423,664	1,441,000	1,520,000
Development	0	0	0
Subtotal, Conduct of R&D	96,745,629	97,945,000	103,350,000
(Conduct of R&D Performed by Colleges and Universities.)	(95,277,262)	(96,459,000)	(101,782,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	96,745,629	97,945,000	103,350,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$96,745,629	$97,945,000	$103,350,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,975	1,990	2,110
Dollars Requested (Total)	$399,369,589	$404,323,165	$426,635,000
Action Summary			
Number of Awards	1,151	1,165	1,230
Dollars Obligated(Total)	96,745,629	97,945,000	103,350,000
Average Award Size	84,053	84,000	84,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	95,277,262	96,459,000	101,782,000
Industry	113,502	115,000	121,000
Federal Agencies	305,816	310,000	327,000
Other	1,048,449	1,061,000	1,120,000
Personnel			
Senior Scientists			
Number of Scientists Supported	985	997	1,052
Amount of Scientist Support	7,148,126	7,257,000	7,658,000
Number of Years of Scientist Support	126	128	135
Postdoctoral Support			
Number of Postdoctorals Supported	600	615	641
Amount Postdoctoral Support	10,452,255	10,582,000	11,166,000
Graduate Students			
Number of Graduate Students Supported	1,497	1,516	1,599
Amount Graduate Student Support	16,048,285	16,247,000	17,144,000
Other Personnel Costs			
Amount of Support	6,317,822	6,397,000	6,769,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	17,450,872	17,447,000	18,442,000
Other Direct Research Costs*	15,310,049	15,500,000	16,355,000
Indirect Costs	23,997,700	24,295,000	25,636,000
TOTAL	$96,745,629	$97,945,000	$103,350,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MATERIALS RESEARCH

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$108,383,881	$110,131,000	$116,272,000
Applied Research	5,704,415	5,796,000	6,120,000
Development	0	0	0
Subtotal, Conduct of R&D	114,088,296	115,927,000	122,392,000
(Conduct of R&D Performed by Colleges and Universities.)	(113,178,836)	(115,003,000)	(121,416,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	995,900	1,012,000	1,068,000
Subtotal, R&D Facilities & Major Equipment	995,900	1,012,000	1,068,000
Total, Support of R&D	115,084,196	116,939,000	123,460,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$115,084,196	$116,939,000	$123,460,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,995	2,027	2,140
Dollars Requested (Total)	$553,874,635	$562,801,394	$594,186,000
Action Summary			
Number of Awards	872	886	935
Dollars Obligated(Total)	115,084,196	116,939,000	123,460,000
Average Award Size	131,977	132,000	132,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	113,178,836	115,003,000	121,416,000
Industry	195,200	198,000	209,000
Federal Agencies	1,218,000	1,238,000	1,307,000
Other	492,160	500,000	528,000
Personnel			
Senior Scientists			
Number of Scientists Supported	1,211	1,231	1,299
Amount of Scientist Support	10,349,193	10,516,000	11,102,000
Number of Years of Scientist Support	171	174	183
Postdoctoral Support			
Number of Postdoctorals Supported	430	437	461
Amount Postdoctoral Support	7,748,171	7,873,000	8,312,000
Graduate Students			
Number of Graduate Students Supported	1,626	1,650	1,742
Amount Graduate Student Support	18,424,765	18,722,000	19,766,000
Other Personnel Costs			
Amount of Support	13,368,893	13,584,000	14,342,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	995,900	1,012,000	1,068,000
Other Equipment and Instrumentation	15,110,529	15,354,000	16,210,000
Other Direct Research Costs*	18,224,656	18,518,000	19,551,000
Indirect Costs	30,862,089	31,360,000	33,109,000
TOTAL	$115,084,196	$116,939,000	$123,460,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

SCIENCE AND TECHNOLOGY CENTERS - MPS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$10,763,475	$11,218,000	$20,871,000
Applied Research	1,002,841	1,045,000	1,944,000
Development	0	0	0
Subtotal, Conduct of R&D	11,766,316	12,263,000	22,815,000
(Conduct of R&D Performed by Colleges and Universities.)	(11,766,316)	(12,263,000)	(22,815,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	2,181,093	2,273,000	4,225,000
Subtotal, R&D Facilities & Major Equipment	2,181,093	2,273,000	4,225,000
Total, Support of R&D	13,947,409	14,536,000	27,040,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$13,947,409	$14,536,000	$27,040,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	306	73	0
Dollars Requested (Total)	$397,498	$197,409	$0
Action Summary			
Number of Awards	6	6	12
Dollars Obligated(Total)	13,947,409	14,536,000	27,040,000
Average Award Size	2,324,568	2,422,700	2,253,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	13,947,409	14,536,000	27,040,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	76	108	201
Amount of Scientist Support	774,012	807,000	1,500,000
Number of Years of Scientist Support	21	38	45
Postdoctoral Support			
Number of Postdoctorals Supported	47	49	91
Amount Postdoctoral Support	660,597	688,000	1,281,000
Graduate Students			
Number of Graduate Students Supported	53	55	102
Amount Graduate Student Support	597,039	622,000	1,157,000
Other Personnel Costs			
Amount of Support	1,070,541	1,115,000	2,075,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment			
Major Equipment	2,181,093	2,273,000	4,225,000
Other Equipment and Instrumentation	1,861,900	1,886,000	2,820,000
Other Direct Research Costs*	5,735,967	5,978,000	11,125,000
Indirect Costs	1,886,280	1,967,000	3,657,000
TOTAL	$13,947,409	$14,536,000	$27,040,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MAJOR RESEARCH EQUIPMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	0	0	0
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	2,300,000	44,000,000
Major Equipment	500,000	40,690,000	19,000,000
Subtotal, R&D Facilities & Major Equipment	500,000	42,990,000	63,000,000
Total, Support of R&D	500,000	42,990,000	63,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$500,000	$42,990,000	$63,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	2	11	0
Dollars Requested (Total)	$251,000,000	$331,800,000	$0
Action Summary			
Number of Awards	1	2	4
Dollars Obligated(Total)	500,000	42,990,000	63,000,000
Average Award Size	500,000	21,495,000	15,750,000
Average Award Duration (Years)	1.0	5.0	1.0
Dollar Distribution by Performer			
Universities	0	6,000,000	59,000,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	500,000	36,990,000	4,000,000
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	2,300,000	44,000,000
Major Equipment*	500,000	40,690,000	19,000,000
Other Equipment and Instrumentation**	0	0	0
Other Direct Research Costs***	0	0	0
Indirect Costs	0	0	0
TOTAL	$500,000	$42,990,000	$63,000,000

*Includes salaries, supplies, and other costs for constructed equipment.
**Does not include salaries, supplies, and other costs for constructed equipment.
***Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

RESEARCH FACILITIES MODERNIZATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	0	0	0
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	19,690,000	20,000,000
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	19,690,000	20,000,000
Total, Support of R&D	0	19,690,000	20,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$0	$19,690,000	$20,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	0	N/A *	N/A *
Dollars Requested (Total)	$0	N/A *	N/A *
Action Summary			
Number of Awards	0	0	0
Dollars Obligated(Total)	0	19,690,000	20,000,000
Average Award Size			
Average Award Duration(Years)			
Dollar Distribution by Performer			
Universities	0	0	0
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	19,690,000	20,000,000
Personnel	0	0	0
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	19,690,000	20,000,000
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs	0	0	0
Indirect Costs	0	0	0
TOTAL	0	$19,690,000	$20,000,000

* Program solicitation issued January 1990; proposals due in March 1990.

SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$40,716,821	$44,130,428	$51,991,000
Applied Research	13,290,517	14,009,655	16,018,000
Development	0	0	0
Subtotal, Conduct of R&D	54,007,338	58,140,080	68,009,000
(Conduct of R&D Performed by Colleges and Universities.)	(30,983,793)	(34,140,870)	(40,856,000)
R&D Facilities			
Land, Building and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	54,007,338	58,140,080	68,009,000
Education and Training	0	0	0
Other, including Collection of Information	4,303,668	5,327,917	5,991,000
TOTAL	$58,311,006	$63,468,000	$74,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	3,382	3,535	3,997
Dollars Requested (Total)	$352,315,741	386,397,111	$460,073,000
Action Summary			
Number of Awards	947	1,037	1,108
Dollars Obligated(Total)	58,311,006	63,468,000	74,000,000
Average Award Size	61,574	61,000	67,000
Dollar Distribution by Performer			
Universities	31,230,840	34,450,870	41,205,000
Industry	22,550,063	24,075,710	27,353,000
Federal Agencies	1,573,778	1,858,275	2,066,000
Other	2,956,325	3,083,145	3,376,000
Personnel			
Senior Scientists			
Number of Scientists Supported	1,256	1,380	1,629
Amount of Scientist Support	10,918,820	11,921,924	14,018,000
Number of Years of Scientist Support	174	188	216
Postdoctoral Support			
Number of Postdoctorals Supported	60	68	83
Amount Postdoctoral Support	929,482	1,050,126	1,293,000
Graduate Students			
Number of Graduate Students Supported	323	363	443
Amount Graduate Student Support	2,098,123	2,358,143	2,882,000
Other Personnel Costs			
Amount of Support	7,094,084	7,920,178	9,352,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	3,350,157	3,767,382	4,619,000
Other Direct Research Costs*	22,022,295	23,494,638	26,845,000
Indirect Costs	11,898,045	12,955,609	14,991,000
TOTAL	$58,311,006	$63,468,000	$74,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

SCIENCE RESOURCES STUDIES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	162,816	283,000	229,000
Development	0	0	0
Subtotal, Conduct of R&D	162,816	283,000	229,000
(Conduct of R&D Performed by Colleges and Universities.)	(162,816)	(283,000)	(229,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	162,816	283,000	229,000
Education and Training	0	0	0
Other, including Collection of Information	4,089,224	5,110,000	5,761,000
TOTAL	$4,252,040	$5,313,000	$5,990,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	54	67	76
Dollars Requested (Total)	$6,359,919	$7,947,000	$8,959,000
Action Summary			
Number of Awards	47	59	66
Dollars Obligated(Total)	4,252,040	5,313,000	5,990,000
Average Award Size	90,469	90,000	90,000
Average Award Duration(Years)	1.1	1.1	1.1
Dollar Distribution by Performer			
Universities	410,263	513,000	578,000
Industry	2,158,972	2,697,000	3,041,000
Federal Agencies	1,137,780	1,422,000	1,603,000
Other	545,025	681,000	768,000
Personnel			
Senior Scientists			
Number of Scientists Supported	87	109	123
Amount of Scientist Support	613,284	766,000	864,000
Number of Years of Scientist Support	14	18	20
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	5	6	7
Amount Graduate Student Support	27,506	34,000	39,000
Other Personnel Costs			
Amount of Support	1,049,280	1,311,000	1,478,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	1,233,640	1,541,000	1,738,000
Indirect Costs	1,328,330	1,661,000	1,871,000
TOTAL	$4,252,040	$5,313,000	$5,990,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

POLICY RESEARCH AND ANALYSIS

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	678,323	671,483	677,000
Development	0	0	0
Subtotal, Conduct of R&D	678,323	671,483	677,000
(Conduct of R&D Performed by Colleges and Universities.)	(23,923)	(23,646)	(24,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	678,323	671,483	677,000
Education and Training	0	0	0
Other, including Collection of Information	173,523	171,517	173,000
TOTAL	$851,846	$843,000	$850,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	14	14	14
Dollars Requested (Total)	$1,301,240	$1,287,727	$1,298,000
Action Summary			
Number of Awards	14	14	14
Dollars Obligated(Total)	851,846	843,000	850,000
Average Award Size	60,846	60,214	61,000
Average Award Duration(Years)	0.3	0.3	0.3
Dollar Distribution by Performer			
Universities	23,923	23,646	24,000
Industry	754,400	746,680	753,000
Federal Agencies	73,523	72,674	73,000
Other	0	0	0
Personnel			
Senior Scientists		0	
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	630,272	623,987	629,000
Indirect Costs	221,574	219,013	221,000
TOTAL	$851,846	$843,000	$850,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

RESEARCH INITIATION AND IMPROVEMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$21,216,652	$24,085,000	$29,746,000
Applied Research	1,673,945	1,898,600	2,347,000
Development	0	0	0
Subtotal, Conduct of R&D	22,890,597	25,983,600	32,093,000
(Conduct of R&D Performed by Colleges and Universities.)	(22,890,597)	(25,983,600)	(32,093,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	22,890,597	25,983,600	32,093,000
Education and Training	0	0	0
Other, including Collection of Information	40,921	46,400	57,000
TOTAL	$22,931,518	$26,030,000	$32,150,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	389	441	545
Dollars Requested (Total)	$201,070,438	228,050,700	$281,896,000
Action Summary			
Number of Awards	136	200	191
Dollars Obligated(Total)	22,931,518	26,030,000	32,150,000
Average Award Size	168,614	130,000	169,000
Average Award Duration(Years)	0.9	0.9	0.9
Dollar Distribution by Performer			
Universities	22,890,597	25,983,600	32,093,000
Industry	0	0	0
Federal Agencies	0	0	0
Other	40,921	46,400	57,000
Personnel			
Senior Scientists			
Number of Scientists Supported	539	611	756
Amount of Scientist Support	4,282,271	4,856,900	6,004,000
Number of Years of Scientist Support	32	36	45
Postdoctoral Support			
Number of Postdoctorals Supported	56	64	79
Amount Postdoctoral Support	892,936	1,012,000	1,252,000
Graduate Students			
Number of Graduate Students Supported	284	322	398
Amount Graduate Student Support	1,865,715	2,104,700	2,602,000
Other Personnel Costs			
Amount of Support	3,299,249	3,742,000	4,625,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	2,956,311	3,353,000	4,145,000
Other Direct Research Costs*	6,708,241	7,720,600	9,518,000
Indirect Costs	2,866,795	3,240,000	4,004,000
TOTAL	$22,931,518	$26,030,000	$32,150,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

INDUSTRIAL SCIENCE AND TECHNOLOGICAL INNOVATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$9,882,169	$10,397,542	$11,893,000
Applied Research	9,170,307	9,648,458	11,037,000
Development	0	0	0
Subtotal, Conduct of R&D	19,052,476	20,046,000	22,930,000
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	19,052,476	20,046,000	22,930,000
Education and Training	0	0	0
Other, Including Collection of Information	0	0	0
TOTAL	$19,052,476	$20,046,000	$22,930,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,678	1,765	2,019
Dollars Requested (Total)	$105,165,800	$110,649,270	$126,568,000
Action Summary			
Number of Awards	233	245	280
Dollars Obligated(Total)	19,052,476	20,046,000	22,930,000
Average Award Size	81,770	82,000	82,000
Average Award Duration(Years)	0.7	0.7	0.7
Dollar Distribution by Performer			
Universities	0	0	0
Industry	19,052,476	20,046,000	22,930,000
Federal Agencies	0	0	0
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	571	601	687
Amount of Scientist Support	5,242,142	5,515,474	6,309,000
Number of Years of Scientist Support	111	117	134
Postdoctoral Support			
Number of Postdoctorals Supported	2	2	2
Amount Postdoctoral Support	13,593	14,302	16,000
Graduate Students			
Number of Graduate Students Supported	13	14	16
Amount Graduate Student Support	79,002	83,121	95,000
Other Personnel Costs			
Amount of Support	2,306,383	2,426,641	2,776,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	393,846	414,382	474,000
Other Direct Research Costs*	4,471,565	4,704,823	5,382,000
Indirect Costs	6,545,945	6,887,257	7,878,000
TOTAL	$19,052,476	$20,046,000	$22,930,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$9,618,000	$9,667,886	$10,352,000
Applied Research	1,605,126	1,568,114	1,728,000
Development	0	0	0
Subtotal, Conduct of R&D	11,223,126	11,236,000	12,080,000
(Conduct of R&D Performed by Colleges and Universities.)	(7,906,057)	(7,930,626)	(8,510,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	11,223,126	11,236,000	12,080,000
Education and Training	0	0	0
Other, Including Collection of Information	0	0	0
TOTAL	$11,223,126	$11,236,000	$12,080,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	1,247	1,248	1,342
Dollars Requested (Total)	$38,418,344	$38,462,414	$41,352,000
Action Summary			
Number of Awards	517	519	556
Dollars Obligated(Total)	11,223,126	11,236,000	12,080,000
Average Award Size	21,708	22,000	22,000
Average Award Duration(Years)	1.7	1.7	1.7
Dollar Distribution by Performer			
Universities	7,906,057	7,930,626	8,510,000
Industry	584,215	586,030	629,000
Federal Agencies	362,475	363,601	390,000
Other	2,370,379	2,355,746	2,551,000
Personnel			
Senior Scientists			
Number of Scientists Supported	59	59	64
Amount of Scientist Support	781,123	783,550	841,000
Number of Years of Scientist Support	17	17	18
Postdoctoral Support			
Number of Postdoctorals Supported	2	2	2
Amount Postdoctoral Support	22,953	23,024	25,000
Graduate Students			
Number of Graduate Students Supported	21	21	23
Amount Graduate Student Support	135,900	136,322	146,000
Other Personnel Costs			
Amount of Support	439,172	440,537	475,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	8,898,577	8,904,228	9,576,000
Indirect Costs	945,401	948,339	1,017,000
TOTAL	$11,223,126	$11,236,000	$12,080,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

PROGRAM DEVELOPMENT AND MANAGEMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$79,261,358	$83,687,000	$88,998,000
Applied Research	7,499,138	7,917,800	$8,420,000
Development	0	0	$0
Subtotal, Conduct of R&D	86,760,496	91,604,800	97,418,000
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	912,735	963,700	1,025,000
Major Equipment	1,787,444	1,887,200	2,007,000
Subtotal, R&D Facilities & Major Equipment	2,700,179	2,850,900	3,032,000
Total, Support of R&D	89,460,675	94,455,700	100,450,000
Education and Training	0	0	0
Collection of Information	1,825,351	1,927,300	2,050,000
TOTAL	$91,286,026	$96,383,000	$102,500,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	0	0	0
Dollars Requested (Total)	$0	$0	$0
Action Summary			
Number of Awards	0	0	0
Dollars Obligated(Total)	91,286,026	96,383,000	102,500,000
Average Award Size			
Average Award Duration(Years)			
Dollar Distribution by Performer			
Universities	0	0	0
Industry	0	0	0
Federal Agencies	0	0	0
Other	91,286,026	96,383,000	102,500,000
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	0	0	0
Indirect Costs	91,286,026	96,383,000	102,500,000
TOTAL	91,286,026	96,383,000	102,500,000

*Includes: Supplies, Publications, Consultants, Computer Subcontracts, Travel.

NSF HEADQUARTERS RELOCATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$5,024,600
Applied Research	0	0	475,400
Development	0	0	0
Subtotal,Conduct of R&D	0	0	5,500,000
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	0	0	5,500,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$0	$0	$5,500,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	0	0	0
Dollars Requested (Total)	$0	$0	$0
Action Summary			
Number of Awards	0	0	0
Dollars Obligated(Total)	0	0	5,500,000
Average Award Size			
Average Award Duration(Years)			
Dollar Distribution by Performer			
Universities	0	0	0
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	0	5,500,000
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	0	0	0
Indirect Costs	0	0	5,500,000
TOTAL	0	0	5,500,000

*Includes: Supplies, Publications, Consultants, Computer Subcontracts, Travel.

SCIENCE AND ENGINEERING EDUCATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$7,492,774	$7,950,000	$8,250,000
Applied Research	7,862,764	7,745,000	8,150,000
Development	0	0	0
Subtotal, Conduct of R&D	15,355,538	15,695,000	16,400,000
(Conduct of R&D Performed by Colleges and Universities.)	(11,115,366)	(11,480,000)	(11,980,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	15,355,538	15,695,000	16,400,000
Education and Training	155,771,501	188,570,000	234,600,000
Collection of Information	0	0	0
TOTAL	$171,127,039	$204,265,000	$251,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	9,652	11,515	13,285
Dollars Requested (Total)	$966,147,379	$1,063,200,000	$1,162,500,000
Action Summary			
Number of Awards	1,399	1,479	1,645
Dollars Obligated(Total)	171,127,039	204,265,000	251,000,000
Average Award Size	122,321	138,000	153,000
Dollar Distribution by Performer			
Universities	114,420,249	134,060,180	164,863,000
Industry	4,992,098	5,469,881	6,657,000
Federal Agencies	20,000	19,400	22,000
Other	51,694,692	64,715,539	79,458,000
		0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	2,591	2,972	3,475
Amount of Scientist Support	21,413,607	25,702,937	31,488,000
Number of Years of Scientist Support	531	625	767
Postdoctoral Support			
Number of Postdoctorals Supported	103	122	162
Amount Postdoctoral Support	801,822	917,291	1,165,800
Graduate Students			
Number of Graduate Students Supported	1,773	2,531	3,134
Amount Graduate Student Support	23,793,242	30,022,980	36,440,000
Other Personnel Costs			
Amount of Support	15,080,725	17,723,205	22,442,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	16,767,834	17,002,740	24,117,800
Other Direct Costs*	70,454,646	85,692,257	102,733,000
Indirect Costs	22,815,163	27,203,590	32,613,400
TOTAL	$171,127,039	$204,265,000	$251,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

TEACHER PREPARATION AND ENHANCEMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	771,940	900,000	900,000
Development	0	0	0
Subtotal, Conduct of R&D	771,940	900,000	900,000
(Conduct of R&D Performed by Colleges and Universities.)	(759,125)	(880,000)	(880,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	771,940	900,000	900,000
Education and Training	62,890,160	80,100,000	88,700,000
Collection of Information	0	0	0
TOTAL	$63,662,100	$81,000,000	$89,600,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	769	825	875
Dollars Requested (Total)	319,068,162	$350,000,000	$375,000,000
Action Summary			
Number of Awards*	373	450	480
Dollars Obligated(Total)	63,662,100	81,000,000	89,600,000
Average Award Size	170,676	180,000	187,000
Average Award Duration(Years)	2.5	2.5	2.5
Dollar Distribution by Performer			
Universities	43,726,906	50,000,000	52,000,000
Industry	1,566,027	2,000,000	2,500,000
Federal Agencies	0	0	0
Other	18,369,167	29,000,000	35,100,000
Personnel			
Senior Scientists			
Number of Scientists Supported	1,206	1,532	1,695
Amount of Scientist Support	11,476,675	14,602,193	16,153,000
Number of Years of Scientist Support	251	319	353
Postdoctoral Support			
Number of Postdoctorals Supported	37	47	52
Amount Postdoctoral Support	248,268	315,880	349,000
Graduate Students			
Number of Graduate Students Supported	176	221	245
Amount Graduate Student Support	1,315,692	1,674,003	1,852,000
Other Personnel Costs**			
Amount of Support	4,751,453	6,045,447	6,687,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	218,136	277,542	307,000
Other Direct Costs***	35,430,268	45,079,609	49,866,000
Indirect Costs	10,221,608	13,005,326	14,386,000
TOTAL	$63,662,100	$81,000,000	$89,600,000

*Includes 112 Presidential Awards in FY89; 216 projected in FY90, FY91.
Excludes 104 Presidential Award supplements made in FY89

**Includes other professionals (technicians, etc), undergraduate students, secretarial/clerical personnel.

***Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

MATERIALS DEVELOPMENT, RESEARCH, AND INFORMAL SCIENCE EDUCATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$7,492,774	$7,950,000	$8,250,000
Applied Research	2,992,940	3,150,000	3,250,000
Development	0	0	0
Subtotal, Conduct of R&D	10,485,714	11,100,000	11,500,000
(Conduct of R&D Performed by Colleges and Universities.)	(8,129,276)	(8,600,000)	(8,900,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	10,485,714	11,100,000	11,500,000
Education and Training	33,499,752	36,900,000	50,000,000
Collection of Information	0	0	0
TOTAL	$43,985,466	$48,000,000	$61,500,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	246	260	275
Dollars Requested (Total)	141,852,448	$160,000,000	$180,000,000
Action Summary			
Number of Awards	157	160	180
Dollars Obligated (Total)	43,985,466	48,000,000	61,500,000
Average Award Size	280,162	300,000	342,000
Average Award Duration (Years)	2.5	2.5	2.5
Dollar Distribution by Performer			
Universities	16,405,720	18,000,000	22,938,000
Industry	1,284,980	1,400,000	1,797,000
Federal Agencies	0	0	0
Other	26,294,766	28,600,000	36,765,000
Personnel			
Senior Scientists			
Number of Scientists Supported	443	483	619
Amount of Scientist Support	5,700,644	6,220,911	7,971,000
Number of Years of Scientist Support	167	182	234
Postdoctoral Support			
Number of Postdoctorals Supported	17	19	24
Amount Postdoctoral Support	329,706	359,799	461,000
Graduate Students			
Number of Graduate Students Supported	80	97	124
Amount Graduate Student Support	953,476	1,040,495	1,333,000
Other Personnel Costs			
Amount of Support	7,689,426	8,391,196	10,751,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	1,441,805	1,573,391	1,750,000
Other Direct Costs*	19,035,582	20,773,074	26,881,000
Indirect Costs	8,834,827	9,641,134	12,353,000
TOTAL	$43,985,466	$48,000,000	$61,500,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel, and Participant Costs.

UNDERGRADUATE SCIENCE, ENGINEERING AND MATHEMATICS EDUCATION

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	0	0	0
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	0	0	0
Education and Training	27,999,395	34,000,000	50,000,000
Collection of Information	0	0	0
TOTAL	$27,999,395	$34,000,000	$50,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	2,091	2,100	2,800
Dollars Requested (Total)	335,904,335	$350,000,000	$375,000,000
Action Summary			
Number of Awards	562	560	650
Dollars Obligated(Total)	27,999,395	34,000,000	50,000,000
Average Award Size	49,821	61,000	77,000
Average Award Duration(Years)	2.0	2.0	2.0
Dollar Distribution by Performer			
Universities	25,118,542	30,900,000	46,000,000
Industry	853,961	850,000	1,000,000
Federal Agencies	0	0	0
Other	2,026,892	2,250,000	3,000,000
		0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	364	375	500
Amount of Scientist Support	2,344,837	3,000,000	5,000,000
Number of Years of Scientist Support	55	65	90
Postdoctoral Support			
Number of Postdoctorals Supported	28	34	60
Amount Postdoctoral Support	98,982	120,195	215,000
Graduate Students			
Number of Graduate Students Supported	127	154	250
Amount Graduate Student Support	344,480	418,305	675,000
Other Personnel Costs			
Amount of Support	1,321,888	1,800,000	2,500,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	15,054,313	15,100,000	22,000,000
Other Direct Costs*	7,213,944	11,165,500	16,250,000
Indirect Costs	1,620,951	2,396,000	3,360,000
TOTAL	$27,999,395	$34,000,000	$50,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

RESEARCH CAREER DEVELOPMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	0	0	0
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	0	0	0
Education and Training	30,980,129	36,900,000	44,900,000
Collection of Information	0	0	0
TOTAL	$30,980,129	$36,900,000	$44,900,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	6,513	8,295	9,300
Dollars Requested (Total)	155,254,127	$188,200,000	$216,500,000
Action Summary			
Number of Awards**	283	285	310
Dollars Obligated(Total)	30,980,129	36,900,000	44,900,000
Average Award Size	109,470	129,000	145,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	26,942,116	33,000,000	41,450,000
Industry	648,085	600,000	650,000
Federal Agencies	0	0	0
Other	3,389,928	3,300,000	2,800,000
Personnel			
Senior Scientists			
Number of Scientists Supported	552	555	630
Amount of Scientist Support	1,577,196	1,575,000	2,015,000
Number of Years of Scientist Support	50	51	61
Postdoctoral Support			
Number of Postdoctorals Supported	14	15	18
Amount Postdoctoral Support	11,549	11,500	14,800
Graduate Students			
Number of Graduate Students Supported	1,379	2,055	2,510
Amount Graduate Student Support	21,107,247	26,820,000	32,500,000
Other Personnel Costs			
Amount of Support	953,983	1,133,500	2,100,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	10,480	10,000	12,800
Other Direct Costs*	5,863,468	5 850,000	6,500,000
Indirect Costs	1,456,208	1,500,000	1,757,400
TOTAL	$30,980,129	$36,900,000	$44,900,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.
**These awards to various institutions include 1925 fellowships in FY 1989;
2300 fellowships in FY 1990; and 2600 fellowships in FY 1991.

STUDIES AND PROGRAM ASSESSMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	4,097,884	3,695,000	4,000,000
Development	0	0	0
Subtotal, Conduct of R&D	4,097,884	3,695,000	4,000,000
(Conduct of R&D Performed by Colleges and Universities.)	(2,226,965)	(2,000,000)	(2,200,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	4,097,884	3,695,000	4,000,000
Education and Training	402,065	670,000	1,000,000
Collection of Information	0	0	0
TOTAL	$4,499,949	$4,365,000	$5,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	35	35	35
Dollars Requested (Total)	$14,068,307	$15,000,000	$16,000,000
Action Summary			
Number of Awards	24	24	25
Dollars Obligated(Total)	4,499,949	4,365,000	5,000,000
Average Award Size	187,498	182,000	200,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	2,226,965	2,160,180	2,475,000
Industry	639,045	619,881	710,000
Federal Agencies	20,000	19,400	22,000
Other	1,613,939	1,565,539	1,793,000
Personnel			
Senior Scientists			
Number of Scientists Supported	28	27	31
Amount of Scientist Support	314,257	304,833	349,000
Number of Years of Scientist Support	8	8	9
Postdoctoral Support			
Number of Postdoctorals Supported	7	7	8
Amount Postdoctoral Support	113,315	109,917	126,000
Graduate Students			
Number of Graduate Students Supported	4	4	4
Amount Graduate Student Support	72,347	70,177	80,000
Other Personnel Costs			
Amount of Support	363,977	353,062	404,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	43,100	41,807	48,000
Other Direct Costs*	2,911,384	2,824,074	3,236,000
Indirect Costs	681,569	661,130	757,000
TOTAL	$4,499,949	$4,365,000	$5,000,000

*Includes: Supplies, Publications, Consultants, Computer Services, Subcontracts, Travel.

U.S. ANTARCTIC PROGRAM

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$117,897,067	$134,518,100	$152,697,000
Applied Research	300,000	336,859	373,000
Development	0	0	0
Subtotal, Conduct of R&D	118,197,067	134,854,959	153,070,000
(Conduct of R&D Performed by Colleges and Universities.)	(15,390,167)	(16,861,719)	(19,611,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	12,872,000	16,827,041	21,930,000
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	12,872,000	16,827,041	21,930,000
Total, Support of R&D	131,069,067	151,682,000	175,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$131,069,067	$151,682,000	$175,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	358	394	440
Dollars Requested (Total)	$160,639,000	$185,905,899	$215,097,000
Action Summary			
Number of Awards	195	219	245
Dollars Obligated(Total)	131,069,067	151,682,000	175,000,000
Average Award Size	672,149	693,000	715,000
Dollar Distribution by Performer			
Universities	15,390,067	16,861,719	19,611,000
Industry	40,315,000	55,668,671	74,726,000
Federal Agencies	74,299,000	77,980,175	79,358,000
Other	1,065,000	1,171,435	1,305,000
Personnel			
Senior Scientists			
Number of Scientists Supported	289	316	353
Amount of Scientist Support	2,855,000	3,119,720	3,483,000
Number of Years of Scientist Support	62	68	76
Postdoctoral Support			
Number of Postdoctorals Supported	36	39	44
Amount Postdoctoral Support	538,000	587,884	656,000
Graduate Students			
Number of Graduate Students Supported	110	120	134
Amount Graduate Student Support	1,097,000	1,198,715	1,338,000
Other Personnel Costs			
Amount of Support	35,680,000	39,979,819	44,286,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	12,872,000	16,827,000	26,930,000
Major Equipment	0	0	0
Other Equipment and Instrumentation	16,510,000	21,114,994	22,009,000
Other Direct Research Costs	57,307,067	64,244,679	71,155,000
Indirect Costs	4,210,000	4,609,189	5,143,000
TOTAL	$131,069,067	$151,682,000	$175,000,000

U.S. ANTARCTIC RESEARCH PROGRAM

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$15,572,030	$17,016,000	$19,000,000
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	15,572,030	17,016,000	19,000,000
(Conduct of R&D Performed by Colleges and Universities.)	(13,962,130)	(15,256,719)	(17,036,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	15,572,030	17,016,000	19,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$15,572,030	$17,016,000	$19,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	322	352	393
Dollars Requested (Total)	$30,639,000	$33,479,892	$37,384,000
Action Summary			
Number of Awards	175	196	218
Dollars Obligated(Total)	15,572,030	17,016,000	19,000,000
Average Award Size	88,983	86,816	87,156
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	13,962,030	15,256,719	17,036,000
Industry	320,000	349,671	390,000
Federal Agencies	498,000	544,175	608,000
Other	792,000	865,435	966,000
Personnel			
Senior Scientists			
Number of Scientists Supported	289	316	353
Amount of Scientist Support	2,855,000	3,119,720	3,483,000
Number of Years of Scientist Support	62	68	76
Postdoctoral Support			
Number of Postdoctorals Supported	36	39	44
Amount Postdoctoral Support	538,000	587,884	656,000
Graduate Students			
Number of Graduate Students Supported	110	120	134
Amount Graduate Student Support	1,097,000	1,198,715	1,338,000
Other Personnel Costs			
Amount of Support	2,784,000	3,042,136	3,397,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	951,000	1,039,178	1,160,000
Other Direct Research Costs	3,430,030	3,748,177	4,187,000
Indirect Costs	3,917,000	4,280,190	4,779,000
TOTAL	$15,572,030	$17,016,000	$19,000,000

ANTARCTIC OPERATIONS PROGRAM

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$88,197,037	$99,033,141	$109,627,000
Applied Research	300,000	336,859	373,000
Development	0	0	0
Subtotal, Conduct of R&D	88,497,037	99,370,000	110,000,000
(Conduct of R&D Performed by Colleges and Universities.)	(1,428,037)	(1,605,000)	(2,575,000)
R&D Facilities			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	88,497,037	99,370,000	110,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$88,497,037	$99,370,000	$110,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	31	35	39
Dollars Requested (Total)	$95,000,000	$106,671,933	$118,083,000
Action Summary			
Number of Awards	16	18	20
Dollars Obligated(Total)	88,497,037	99,370,000	110,000,000
Average Award Size	5,531,000	5,521,000	5,530,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	1,428,037	1,605,000	2,575,000
Industry	26,923,000	36,230,000	45,065,000
Federal Agencies	59,873,000	61,229,000	62,021,000
Other	273,000	306,000	339,000
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	32,896,000	36,937,683	40,889,000
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	1,431,000	1,606,816	1,779,000
Other Direct Research Costs	53,877,037	60,496,502	66,968,000
Indirect Costs	293,000	328,999	364,000
TOTAL	$88,497,037	$99,370,000	$110,000,000

MAJOR CONSTRUCTION AND PROCUREMENT

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$14,128,000	$18,468,959	$24,070,000
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	14,128,000	18,468,959	24,070,000
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Buildings and Fixed Equipment	12,872,000	16,827,041	21,930,000
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	12,872,000	16,827,041	21,930,000
Total, Support of R&D	27,000,000	35,296,000	46,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$27,000,000	$35,296,000	$46,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	5	7	9
Dollars Requested (Total)	$35,000,000	$45,754,074	$59,630,000
Action Summary			
Number of Awards	4	5	7
Dollars Obligated(Total)	27,000,000	35,296,000	46,000,000
Average Award Size	6,750,000	7,059,200	6,755,000
Average Award Duration(Years)	1.0	1.0	1.0
Dollar Distribution by Performer			
Universities	0	0	0
Industry	13,072,000	19,089,000	29,271,000
Federal Agencies	13,928,000	16,207,000	16,729,000
Other	0	0	0
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	12,872,000	16,827,000	26,930,000
Major Equipment	0	0	0
Other Equipment and Instrumentation	14,128,000	18,469,000	19,070,000
Other Direct Research Costs	0	0	0
Indirect Costs	0	0	0
TOTAL	$27,000,000	$35,296,000	$46,000,000

OFFICE OF INSPECTOR GENERAL

Research and Development Special Analysis

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Support of R&D			
Conduct of Research			
Basic Research	$0	$0	$0
Applied Research	0	0	0
Development	0	0	0
Subtotal, Conduct of R&D	0	0	0
(Conduct of R&D Performed by Colleges and Universities.)	0	0	0
R&D Facilities			
Land, Building and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Subtotal, R&D Facilities & Major Equipment	0	0	0
Total, Support of R&D	0	0	0
Non-Investment Activities	0	2,560,000	3,000,000
Education and Training	0	0	0
Collection of Information	0	0	0
TOTAL	$0	$2,560,000	$3,000,000

Quantitative Data Table

	Actual FY 1989	Estimate FY 1990	Estimate FY 1991
Proposal Summary			
Number of Proposals Received	0	0	0
Dollars Requested (Total)	$0	$0	$0
Action Summary			
Number of Awards	0	0	0
Dollars Obligated(Total)	0	2,560,000	3,000,000
Average Award Size	0	0	0
Average Award Duration(Years)			
Dollar Distribution by Performer			
Universities	0	0	0
Industry	0	0	0
Federal Agencies	0	0	0
Other	0	2,560,000	3,000,000
Personnel			
Senior Scientists			
Number of Scientists Supported	0	0	0
Amount of Scientist Support	0	0	0
Number of Years of Scientist Support	0	0	0
Postdoctoral Support			
Number of Postdoctorals Supported	0	0	0
Amount Postdoctoral Support	0	0	0
Graduate Students			
Number of Graduate Students Supported	0	0	0
Amount Graduate Student Support	0	0	0
Other Personnel Costs			
Amount of Support	0	0	0
R&D Facilities, Equipment and Instrumentation			
Land, Buildings and Fixed Equipment	0	0	0
Major Equipment	0	0	0
Other Equipment and Instrumentation	0	0	0
Other Direct Research Costs*	0	0	0
Indirect Costs	0	0	0
Non-Investment Activities	0	2,560,000	3,000,000
TOTAL	0	2,560,000	3,000,000

*Includes: Supplies, Publications, Consultants, Computer Subcontracts, Travel.

National Science Foundation

WASHINGTON, D.C. 20550

BUDGET SUMMARY

Fiscal Year 1991

SUMMARY BUDGET INFORMATION BY ACTIVITY AND APPROPRIATION: FY 1989-FY 1991

(Dollars in Thousands)

	Actual FY1989	Request FY1990	Current Plan FY 1990*	Estimate FY1991	Difference	Percent
RESEARCH AND RELATED ACTIVITIES						
Biological, Behavioral and Social Sciences	$281,469	$314,500	$293,535	$327,525	$33,990	11.6%
Computer and Information Science and Engineering	151,838	191,200	169,792	193,250	23,458	13.8
Engineering	187,065	211,200	200,221	226,000	25,779	12.9
Geosciences	309,909	341,300	325,006	383,725	58,719	18.1
Mathematical and Physical Sciences	503,803	553,500	557,006	621,500	64,494	11.6
Research Facilities Modernization	0	0	19,690	20,000	310	N/A
Science and Technology Centers	0	20,000	0	0	0	N/A
Scientific, Technological and International Affairs	58,311	67,322	63,468	74,000	10,532	6.6
Program Development and Management	91,286	104,000	96,383	102,500	6,117	6.3
NSF Headquarters Relocation	0	0	0	5,500	5,500	N/A
Subtotal, Research and Related Activities Appropriation	1,583,681	1,803,022	1,725,101	1,954,000	228,899	13.3
Carryover 1989	0	0	37,951	0	-37,951	-100.0
Total, Research and Related Activities	$1,583,681	$1,803,022	$1,763,052	$1,954,000	$190,948	10.8%
SCIENCE AND ENGINEERING EDUCATION						
Teacher Preparation and Enhancement	63,662	68,500	81,000	89,600	8,600	10.6%
Materials Development, Research and Informal Science Education	43,986	49,000	48,000	61,500	13,500	28.1
Undergraduate Science, Engineering and Mathematics Education	27,999	30,000	34,000	50,000	16,000	47.1
Research Career Development	30,980	38,000	36,900	44,900	8,000	21.7
Studies and Program Assessment	4,500	4,500	4,365	5,000	635	14.5
Subtotal, Science and Engineering Education Appropriation	171,127	190,000	204,265	251,000	46,735	22.9
Carryover 1989	0	0	61	0	-61	-100.0
Total, Science and Engineering Education	171,127	190,000	204,326	251,000	46,674	22.8%
U.S. ANTARCTIC RESEARCH PROGRAM						
U.S. Antarctic Research Program	15,572	17,500	17,016	19,000	1,984	11.7%
Operations Support	88,497	102,200	99,370	110,000	10,630	10.7
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704	30.3
Subtotal, U.S. Antarctic Research Program Appropriation	131,069	156,000	151,682	175,000	23,318	15.4
Carryover 1989	0	0	171	0	-171	-100.0
Subtotal, U.S. Antarctic Research Program	131,069	156,000	151,853	175,000	23,147	15.2%
OFFICE OF INSPECTOR GENERAL	0	0	2,560	3,000	440	17.2%
Subtotal, NSF APPROPRIATION	1,885,877	2,149,022	2,083,608	2,383,000	299,392	14.4%
Carryover 1989	0	0	38,183	0	-38,183	-100.0
TOTAL, NSF	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209	12.3%

* Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

NATIONAL SCIENCE FOUNDATION
FY 1991 BUDGET REQUEST

OVERVIEW

The National Science Foundation (NSF) Budget Request for FY 1991 is $2.38 billion, an increase of $299 million or 14.4 percent over the FY 1990 Current Plan. The request includes the following appropriations:

(Millions of Dollars)

Account	FY 1990 Current Plan	FY 1991 Request	Change 90/91	Percent Increase
Research and Related Activities	$1,725.1	$1,954.0	$228.9	13.3%
U.S. Antarctic Program	151.7	175.0	23.3	15.4
Science and Engineering Education	204.3	251.0	46.7	22.9
Office of Inspector General	2.6	3.0	0.4	17.2
Total, NSF	$2,083.6	$2,383.0	$299.4	14.4%

The FY 1991 Budget signals the start of NSF's fifth decade. In NSF's early years, the country's concerns focused on science and engineering education and research in order to maintain an advantage over a military adversary. Today, education and research remain critical to the country's well-being, not only in terms of national security, but also in terms of economic security. Now,as then, NSF plays a vital role in generating and disseminating new knowledge and supporting the education of a technical workforce.

Because of the central role of research and education in the country's future and despite severe budgetary constraints, the President's plan to double the Foundation's budget is an important investment in the nation's future. This budget provides the funds to bolster significant support for the nation's research infrastructure, thereby strengthening our nation's ability to compete in the world's economy.

In international competition the comparative advantage is no longer determined by access to low wage areas or access to natural resources but by access to sophisticated knowledge and new discoveries and inventions. NSF plays a key role in initiating and stimulating innovative research and developing the knowledge base and educated people necessary to increase our productivity and improve our economic competitiveness. Recent NSF initiatives in biotechnology, supercomputing, and the development of new materials have had major impacts on improving our competitive posture as well as in advancing the knowledge base.

The FY 1991 Request proposes to accelerate global change research, enhances support for disciplinary research, continues growth for the U.S. Antarctic Program Safety, Environmental and Health initiative, and takes advantage of unique scientific opportunities for international, as well as interagency, cooperation.

Equally important, the FY 1991 Request calls for significant growth in education and human resources. NSF plays a key role in the education of the next generation of scientists, engineers and science educators. In FY 1991 the Foundation will support over 28,000 graduate and undergraduate students at some 1200 colleges and universities. In an effort to reverse the downward trend in the number of science and engineering baccalaureates, NSF is investing significantly in precollege and undergraduate education, programs to attract and retain minorities, women and the disabled, and support for new researchers.

The education of future scientists and engineers and the development of new knowledge and its transfer to others are critical to new technologies, products and an improved competitive posture. The FY 1991 Request reflects a strategic framework for a significant and balanced investment in education, the generation of new knowledge, and the transfer of new knowledge from producers to users. It emphasizes support of science and engineering research and education at U.S. universities and colleges, which are the primary source of our technical workforce and the major performers of basic research.

NSF STRATEGY

The FY 1991 Request centers around two strategic themes:

- **Strengthening the research base and improving academic facilities and equipment ($1.81 billion).**

  Support for research and facilities is the dominant mode of NSF support. The FY 1991 budget request for these activities is $1.81 billion, an increase of over 11 percent ($183 million) over the prior year. All major fields of physical and life sciences, engineering and computer sciences, as well as the behavioral and social sciences, are represented through grants to individual and groups of investigators, support of undergraduate and graduate students and postdoctoral researchers, and support for laboratory instrumentation and access to large, specialized centers and facilities, computers, and computer networks.

  Equipment is as necessary a requirement for research as are human resources. The cost of equipment is increasing at a faster rate than inflation, and in many of the sciences, is today beyond the reach of an individual country. Major benefits of sharing such equipment include the more equitable sharing of results between us and our trading partners and the access to scarce resources. For these reasons, we are establishing a joint partnership in the design, construction and operation of new optical telescopes and gravity wave detectors on an international basis. This budget contains the first installment for this new equipment.

  The FY 1991 Request continues the program established in FY 1990 to modernize and improve scientific and engineering research facilities in our colleges, universities, and other institutions.

- **Developing human resources, broadening participation, and improving science and engineering education at all levels ($463 million).**

  The FY 1991 request for education and human resources is $463 million, an increase of 30 percent ($106 million) over the FY 1990 Current Plan. These activities are supported across all areas of the Foundation, recognizing the full spectrum of education and training necessary to sustain the science and engineering education pipeline. This focus on the total pipeline, from kindergarten through postdoctoral training, addresses the loss of students at numerous educational levels.

	FY 1990 Current Plan	FY1991 Request	Change 90/91	Percent Increase
Research and Facilities	$1,627	$1,809	$182	11.2%
Education and Human Resources	357	463	106	29.6

RESEARCH AND FACILITIES

Support for research and facilities continues to be the primary focus of NSF support, accounting for over 75 percent ($1.8 billion) of the FY 1991 budget request. This represents an increase of more than 11 percent over FY 1990 levels.

Continued growth is requested for such forefront, high-priority areas as genetics, biodiversity, materials research, the global change research initiative, arctic research, manufacturing and software engineering research. Many of these areas reflect the growing complexity and multi-disciplinary nature of today's research problems, evidenced by increased coordinated research, shared data and common instrumentation and equipment. And increasingly, the advantages realized by collaborative relationships, scale or unique facilities span agency and national borders. Highlights include:

- The expansion of the President's U.S. Global Change Research Program that seeks to understand, and ultimately predict, future changes in the earth's environment, such as global warming. In FY 1991, NSF support will roughly double, to $103 million. As one of seven federal agencies engaged in this initiative, NSF focuses its support on the basic research necessary to understand and model the Earth's component systems, particularly climate and hydrologic cycles, biosphere's response to climate change, land-margin ecosystems, human dimensions of global change and database establishment and management.
- A joint NSF/USDA/DOE/NIH effort to map and sequence a plant genome. This multidisciplinary research will involve biochemists, geneticists, and computer scientists, and will provide model tools and techniques to facilitate the sequencing of more complex genomes. NSF will also seek co-funding with our international partners.

- Funding for a second class of 10-12 Science and Technology Research Centers, deferred from FY 1990 due to a constrained Research and Related Activities budget.

The Foundation, long a source of support for unique national facilities such as telescopes, research ships, and supercomputers, will respond to several new opportunities in FY 1991 to provide investigators with access to world-class facilities. Three projects in particular demonstrate the Foundation's significant commitment to maintaining U.S. preeminence in gravitational physics and ground-based astronomy, while at the same time leveraging considerable international and interagency support. Highlights include:

- The opportunity to verify and measure the existence of gravitational waves and black holes, thus opening a new window onto the Universe, are objectives of Cal Tech and MIT scientists designing the Laser Interferometer Gravitational Wave Observatory (LIGO). NSF will begin construction of two identical, but widely separated, next-generation detectors in FY 1991, at a total estimated cost of $192 million over four years. Two European groups (United Kingdom/Germany and France/Italy) are planning to build detectors of compatible design and similar costs to the LIGO facility. These detectors, working in concert with LIGO, will permit systematic astrophysical observations in the new field of gravitational wave astronomy. Such international cooperation provides a major opportunity to lower national cost by sharing development, construction and operational expenses necessary to begin research in an entirely new field.
- Recent technological advances in key areas of telescope construction present the opportunity to push telescope performance to new standards of excellence and build facilities that will support qualitatively new kinds of science. Construction of two 8-meter optical/infrared telescopes, one in each hemisphere, will be jointly funded by the U.S. and the United Kingdom and Canada as prospective partners. Design and initial purchase of glass for mirrors will take place in FY 1991, followed by start of construction of the first 8-meter telescope in the northern hemisphere in FY 1992. The project is estimated to take 8 years to complete at a total cost of $176 M, of which the U.S. will provide half.
- New technology in antenna design will significantly improve the performance of the 1000-foot diameter reflector at the Arecibo, Puerto Rico, Observatory. NSF and NASA will split the cost of the two-year, $22 million upgrade.

EDUCATION AND HUMAN RESOURCES

Scientific, technical and economic progress requires careful attention to developing the future pool of human talent. While NSF support for education and human resources spans the education pipeline from grade school through graduate school and research initiation, the FY 1991 Request focuses on activities directed at strategic points in the educational sequence, with a primary goal of attracting and retaining students from populations traditionally underrepresented in the sciences.

The FY 1991 Request includes over $460 million for education and human resource development, an increase of 30 percent, or $106 million over FY 1990. Of this total,

$335 million is for education activities and $128 million for other human resource development activities, such as awards to new investigators and studies and analyses. A summary of NSF's investment by education/professional level, in millions of dollars, is below.

Level	FY1990	FY1991	Increase
K-12	$140M	$165M	17.8%
Undergraduate	90	134	48.4
Graduate/Postdoc/Professional	127	164	29.1%

While education and human resource development efforts take place across all Activities and programs of the Foundation, the preponderance of precollege education activities is located in the Science and Engineering Education Activity. Current pre-college efforts tc improve teaching, materials and informal science education will be complemented by enhanced efforts to forge strong federal-state partnerships to improve lower, middle and high school science and mathematics education across the country.

Undergraduate research and education programs, supported by every Activity, will increase $44 million (48 percent) to a total of $134 million in FY 1991. Key components of this educational thrust are:

- A significant investment in comprehensive curriculum redesign to encompass introductory science, mathematics and engineering courses in all Activities, and Engineering Education Coalitions focusing on comprehensive engineering curriculum reform; and
- An increase in the number of Career Access centers to about 16 in FY 1991 to reduce the loss of talented minority and women students in science, mathematics and engineering.

New Graduate Fellowships will be increased by 100 offers, to a total of 1100. This represents a doubling of Graduate Fellowships over the FY 1987 level, as well as of the Women in Engineering fellowships component over the FY 1990 level (from 80 to 160).

An emerging need is for scientists and engineers trained across traditional disciplinary boundaries. New and enhanced programs to address this need include:

- The Global Change Research Education and Training Program, a new program in FY 1991, which will support approximately 40 postdoctoral appointments, 80 graduate students and 200 undergraduate students as research participants on interdisciplinary global change research problems; and
- Research Training Group awards, which support new or significantly enhanced multidisciplinary training programs at Ph.D.-granting institutions.

Ensuring opportunities for new investigators, as well as encouraging the research careers of young investigators and those new to NSF, is an area of enhanced support in

FY 1991. Special postdoctoral programs in high-need areas such as mathematics, chemistry, environmental biology and plant sciences will receive special attention. The Presidential Young Investigators program will support 200 new awards, for a total of 950. The Request augments research training and initiation programs throughout the Foundation.

At all levels of education and research, NSF has special programs for minority institutions and minority, women and disabled students and investigators. The FY 1991 Request includes almost $94 million for these efforts, or a 48.5 percent increase over the FY 1990 target of $63.1.

In addition to existing programs to assist underrepresented groups, such as Facilitation Awards for the Handicapped, Research Improvement in Minority Institutions, and Research Opportunities for Women, the FY 1991 Request proposes to initiate:

- An Alliances for Minority Participation program to help students complete baccalaureate degrees and make a successful transition to graduate school; and
- A Faculty Recognition Awards for Women program to recognize exemplary women scientists and engineers.

CONCLUSION

By emphasizing human resource development through education and research initiation, and support for core disciplines and facilities, the Foundation's FY 1991 Request is a balanced portfolio of investment in our nation's future. It is an investment designed to nurture the close relationship between basic research and education in science and engineering and, in so doing, improve productivity and economic competitiveness.

ACTIVITY SUMMARIES

RESEARCH AND RELATED ACTIVITIES

Research and Related Activities increases by $228.90 million, or 13.3 percent, over the Current Plan to total $1,954.00 million.

Biological, Behavioral, and Social Sciences (BBS)

The FY 1991 Budget Request for BBS is $327.53 million, or $33.99 million (11.6 percent) over the FY 1990 Current Plan of $293.54 million.

In BBS a major research initiative in plant sciences will support the genome project to map and sequence a model plant system, providing the human resource base necessary to advance research in this important area. Support for individual and group projects will be increased in critical areas of global environmental change and computational biology.

BBS will expand its broad-based initiative on the design and development of shareable biological databases. Understanding biological processes and the ability to capitalize on rapid developments in biological sciences are dependent on the capability to collect, manage, and manipulate large-scale databases.

Increased focus on human resources and education is required to sustain and enhance the recent progress in the life sciences. Approximately $37 million will be available for such activities. Support will focus on research initiation awards for new investigators, research training awards, and postdoctoral fellowships.

Computer and Information Science and Engineering (CISE)

The FY 1991 Budget Request for CISE is $193.25 million, or $23.46 million (13.8 percent) over the FY 1990 Current Plan of $169.79 million.

The CISE Activity will emphasize software information technology to improve research for high performance computing, collaborative work, and experimental application-specific computing systems.

As in FY 1990, CISE will increase activity in advanced scientific computing and networking. The request includes an increase of $7.76 million for four centers to:

- upgrade hardware and software systems;
- undertake an integrated program to improve service offerings; and
- perform new research on computational science software and methods.

NSFNET will increase $9.00 million to better serve the basic research and higher education community through technical upgrades to improve services and security, transition to international protocol standards, and advanced research on very high performance networks and applications.

The CISE disciplines pay special attention not only to undergraduate education but also to human resources development. CISE will provide a $3.00 million increase for undergraduate programs, and will increase the number of research initiation awards and Presidential Young Investigators.

Engineering (ENG)

The FY 1991 Budget Request for ENG is $226.00 million, or $25.78 million (12.9 percent) over the FY 1990 Current Plan of $200.22 million.

The FY 1991 ENG request provides for:

- increased research in high priority areas such as downstream biochemical processing, solid state and microstructures, optical high-speed communications, manufacturing and design and hazards mitigation;
- an increase for Earthquake-related research from $14.32 million to $15.25 million (excluding the transfer of funds in 1990 pursuant to P.L. 101-13-); and
- special research thrust on the processing of advanced materials, including polymers, superconductors, microstructures, composites, and biomaterials.

The Engineering Research Centers program will increase by $7.50 million to $50.10 million in FY 1991. In FY 1991 no additional centers are planned. The increase will allow ENG to address the concern, expressed by the recent National Academy of Engineering study, that current average annual funding for centers is not adequate to achieve the original ERC program objectives.

A new Subactivity, Engineering Infrastructure Development, focuses attention and resources on programs aimed at revitalizing engineering undergraduate education and the infrastructure of the engineering disciplines. Undergraduate engineering programs will increase from $12.40 million to $22.20 million in FY 1991 to:

- develop model undergraduate engineering courses and fund Engineering Education Coalitions that focus on comprehensive curriculum reform;
- provide for increased participation of women and minorities in undergraduate research and education;
- provide for Research Experiences for Undergraduates sites; and
- fund instructional instrumentation and research equipment.

Geosciences (GEO)

The FY 1991 Budget Request for GEO is $383.73 million, or $58.72 million (18.1 percent) over the FY 1990 Current Plan of $325.01 million.

A principal part of the GEO Activity is the Global Geosciences Program, an interrelated set of programs that seek to understand and ultimately predict future changes in the earth's environment. The Global Geosciences Program is a major contributor to the government-wide Global Change initiative. Global Change support at NSF will total $103 million within the BBS and GEO Activities as well as the U.S. Antarctic Program.

In GEO, funding for the Global Geosciences Program will almost double to $85 million, with emphases on:

- climate and hydrologic cycles;
- biogeochemical and ecosystems dynamics;
- earth systems history; and
- establishment and management of databases.

Support for the requisite facilities for conducting laboratory studies, field experiments, and modeling activities will increase to support the National Center for Atmospheric Research, the academic research fleet, instrumentation for the earth sciences, and the Ocean Drilling Program.

The GEO Activity will increase support for programs to improve research opportunities for young investigators and to attract graduate and undergraduate students and minorities to the geosciences. In all, support for the development of human resources increases to $20.28 million.

Mathematical and Physical Sciences (MPS)

The FY 1991 Budget Request for MPS is $621.50 million, or $64.49 million (11.6 percent) over the FY 1990 Current Plan of $557.01 million.

Major research equipment and instrumentation needs across all MPS disciplines are highlighted. Increases are planned for research in special areas of opportunity such as design of special materials, environmental chemistry, and the interaction of mathematics with other disciplines.

Two new construction projects are planned -- a gravity wave observatory and 8-meter optical/infrared telescopes. These major undertakings will contribute to maintaining U.S. leadership in gravitational physics and ground-based astronomy and at the same time take advantage of opportunities for international cooperation. In cooperation with NASA, an upgrade of the Arecibo Observatory will be started. Support will continue for the National High Magnetic Field Laboratory.

Nearly $46 million will be provided in FY 1991 to strengthen human resources, which will emphasize:

- undergraduate curriculum development, particularly at the introductory level for physics, chemistry and mathematics;
- programs to increase the participation of underrepresented groups; and
- support for new investigators.

Research Facilities Modernization (RFM)

The FY 1991 Budget Request for RFM is $20.00 million, or $0.31 million (1.6 percent) over the FY 1990 Current Plan of $19.69 million.

The RFM Activity will provide another $20 million in FY 1991 funds, which together with the 1990 funding provides almost $40 million for awards made as a result of the first competition.

Scientific, Technological, and International Affairs (STIA)

The FY 1991 Budget Request for STIA is $74.00 million, or $10.53 million (16.6 percent) over the FY 1990 Current Plan of $63.47 million.

In STIA, awards under the Small Business Innovation Research (SBIR) Program will provide $22.51 million to small R&D and product-based companies to perform research possibly leading to more rapid commercialization of new high technology products and processes. A new program, College and University Innovation Research (CUIR) will test the SBIR concept in an academic environment.

In International Cooperative Scientific Activities, special attention will be on support of activities related to reopening of scientific communications with Poland, Czechoslovakia, and the U.S.S.R.

Research Initiation and Improvement programs increase over $6.00 million to $32.15 million in order to:

- bolster the Research Careers for Minority Scholars program which is aimed at encouraging talented undergraduate students to begin and continue studies leading to careers in science and engineering;
- continue the Experimental Program to Stimulate Competitive Research (EPSCoR) which assists states in building local resources for science and engineering; and
- hold another competition for two to three new Minority Research Centers of Excellence (MRCE's).

Intramural analyses and other data collection activities will increase to almost $6.00 million to continue the redesign of the Scientific and Technical Personnel Data System (STPDS). This redesign effort represents a commitment by NSF to implement an enhanced system over the next decade.

Program Development and Management (PD&M)

The FY 1991 Budget Request for PD&M is $102.50 million, or $6.12 million (6.3 percent) over the FY 1990 Current Plan of $96.38 million.

The PD&M Activity accounts for only 4.3 percent of the Foundation's total FY 1991 request. It provides funds for staff salaries and other operating expenses necessary to manage and administer the Foundation's program responsibilities, but excludes funds for the Office of the Inspector General which are requested separately.

The increase in PD&M includes:

- $4.40 million for personnel compensation and benefits necessary to cover the cost of the government-wide pay raise and support 1,225 FTE;
- $0.51 million for information systems to continue the conversion of management systems to the mainframe as well as the replacement cycle for personal computer workstations;
- $0.96 million to maintain current levels of essential contract services and building rental and maintenance; and $0.25 million to fund increased levels of support services for travel, training, and printing.

NSF Headquarters Relocation (NHR)

The FY 1991 Budget Request for NHR is $5.50 million.

The NHR Activity is established to accommodate the consolidation of the NSF's two office facilities into a single facility in the Washington Metropolitan Area. In addition to accommodating staff levels needed to support the Foundation's programs, the new facility will:

- provide expanded conferencing facilities for advisory committee and panel review meetings;
- meet NSF's rapidly increasing needs for electronic cabling and networking;
- allow greater flexibility to accommodate organizational changes; and
- improve the overall working environment.

Plans are on schedule for the lease award and site selection to occur in the spring of 1990, and it will take about two years to complete construction. The move to the new building is scheduled to begin in the summer of 1992.

SCIENCE AND ENGINEERING EDUCATION (SEE)

The FY 1991 Budget Request for SEE is $251.0 million or $46.7 (22.9 percent) over the FY 1990 Current Plan of $204.3 million.

Funds for pre-college science and mathematics education increase $24.7 million, or 17.6 percent, over FY 1990, to total $165.1 million. This provides for expansion of the Statewide Initiatives begun in FY 1990, expansion into middle school mathematics of the scientist/educator/publisher model for curriculum projects, and continued support for teacher preparation and enhancement activities, informal science education and the young scholars program.

While undergraduate research and education programs are supported across the Foundation, attention is focused on them in the Undergraduate Science, Engineering and Mathematics Education Subactivity in SEE. SEE's support for undergraduate education will increase 47.1 percent ($16.0 million) over FY 1990 to double support for undergraduate course and curriculum reform in all fields of science, mathematics and engineering, and to support laboratory improvement at all types of institutions. The Career Access Opportunities for Women, Minorities and the Disabled program will be expanded to add three to four centers to the existing twelve.

The number of new Graduate Fellowships will be increased from 960 in FY 1990 to 1060 in FY 1991, for a total of 2560 new and continuing Fellows supported by SEE. In addition, the stipend will be increased to $13,500 in FY 1991.

UNITED STATES ANTARCTIC PROGRAM (USAP)

The FY 1991 Budget Request for USAP is $175.00 million, an increase of $23.32 million, or 15.4 percent, over the FY 1990 Current Plan of $151.68 million.

A major, multi-year Safety, Environment, and Health initiative, which began in FY 1990, will receive an significant increment of $17.00 million in FY 1991, for a total of $25.30 million. The goals of the initiative are:

- Safety: to achieve year-round operations in the Antarctic with modern technology and acceptable risk;
- Environment: to clean up the debris of past operations and to bring present operations into accord with current regulations;
- Health: to improve medical facilities and to provide field parties with safety experts who have medical training.

The incremental funds will provide for activities such as facilities improvements, upgrades of search and rescue communications, improvements in air traffic control systems, expansion of cleanup efforts necessitated by past activities; and measures to minimize future waste production.

Funding for the U.S. Antarctic Research Program, which supports scientific study of the physical and biological environments of Antarctica, will increase by $1.98 million, to $19.00 million, with emphases on geophysics, long-term ecological research, and ocean sciences.

Funding increases for science support, particularly for geophysics research and for an antarctic research vessel, as well as for the increased costs of logistics.

OFFICE OF THE INSPECTOR GENERAL (OIG)

The FY 1991 Budget Request for OIG is $3.0 million or $0.44 million (17.2%) over the FY 1990 Current Plan of $2.56 million. On February 10, 1989 pursuant to the Inspector General Act of 1978 as amended, the National Science Board established the NSF Office of Inspector General. The OIG has responsibility for audit and oversight of the financial, administrative and programmatic aspects of the Foundation's activities. The FY 1991 Request will provide the resouces necessary to support the internal and contract staff needed to accomplish the audit and oversight objectives of the OIG.

DISTRIBUTED AND SPECIAL FOCUS PROGRAMS

The Foundation has developed several programs to strengthen the research infrastructure and develop human resources for science and engineering. All science and engineering research and education activities provide support under these umbrella efforts. Management of the programs is distributed, and closely coupled with the ongoing functions and responsibilities of each Activity. In this way, concerns are addressed in the context of discipline-specific problems and needs.

Science and Technology Centers (STCs)

In FY 1991, $25 million is requested to fund the second class of STCs. Proposals were received in the fall of 1989, and are in merit review at the time of this budget submission. Site visits to the most meritorious proposals are planned for the spring of 1990 and award recommendations will be made to the National Science Board in early fall. Funds for this set of awards are distributed in the four research Activities, based upon proposals in each set of disciplines, as follows:

(Millions of Dollars)

Science and Technology Centers Subactivity	FY 1991 Estimate
Biological, Behavioral and Social Science	$6.325
Computer and Information Science and Engineering	2.750
Geosciences	3.425
Mathematical and Physical Sciences	12.500
Total, STCs	$25.000

Any funding changes that may be required as a result of actual awards will be handled in the FY 1991 Current Plan.

Undergraduate Research and Education

The FY 1991 Request includes $134.23 million for undergraduate research and education, $43.76 million (48.4 percent) over the FY 1990 target. These funds are distributed between the R&RA Account and the SEE Account in order to distribute responsibility for undergraduate activities to all research disciplines.

(Millions of Dollars)

	FY 1990 Estimate	FY 199 Estimate
By Mode of Support:		
Students	$29.57	$38.88
Faculty	19.29	20.39
Instrumentation and Laboratory Improvement	22.28	26.33
Course and Curriculum	16.33	35.47
Other	3.00	13.16
Total, Undergraduate Programs	$90.47	$134.23
By Account:		
Research and Related Activities	$56.47	$84.23
Science and Engineering Education	34.00	50.00

The undergraduate plan is a comprehensive NSF-wide approach to the problems of undergraduate education and is based on the needs of individual disciplines as well as broader educational issues. The undergraduate initiative, which began in FY 1987, includes support for student research, faculty enhancement, course and curriculum development, and instructional instrumentation.

Highlights of the FY 1991 Request include:

- $35 million for course and curriculum development, more than twice the amount estimated for FY 1990;
- $26 million for instrumentation and laboratory improvement, an 18.2 percent increase over FY 1990, for awards to institutions including two- and four-year colleges and research universities; and
- $14 million for research experiences for undergraduates to provide hands-on research experience to undergraduate students.

Underrepresented Groups

Within overall NSF efforts to broaden participation in science and engineering, underrepresented groups receive additional attention. Focus is on women, minorities, and the disabled. This effort involves not only distributed programs, such as Minority Research Initiation (MRI) and Research Opportunities for Women (ROW), but also targeted programs, such as Research Improvement in Minority Institutions (RIMI), Minority Research Centers of Excellence (MRCE), Research Careers for Minority Scholars (RCMS) and Visiting Professorships for Women (VPW) in the R&RA Account and Career Access Opportunities in the SEE Account.

The FY 1991 Request includes $94.08 million for this set of programs, $30.98 million (49.1 percent) over the FY 1990 target.

(Millions of Dollars)

	FY 1990 Estimate	FY 1991 Estimate
By Mode of Support:		
Students	$9.94	$17.80
Faculty	8.85	15.07
Institutions	23.18	39.13
Other	21.13	22.08
Total	$63.10	$94.08
By Account:		
Research and Related Activities	$45.95	$71.53
Science and Engineering Education	17.00	22.55

Two new programs are established in the R&RA Account:

- Faculty Awards for Women will recognize and support outstanding women in science and engineering. These awards will be given annually to 100 young women scientists and engineers nominated by their institutions.
- The Alliances for Minority Participation program will encourage undergraduate minority students to complete their baccalaureate degrees and to pursue graduate studies in science and engineering. Projects will address problems such as retention, support, and inadequate student preparation will emphasize comprehensive approaches to these problems with strong local involvement in project design. In FY 1991, approximately ten institutions will receive awards through this program.

EXPLANATION OF CARRYOVER 1989

In addition to the FY 1990 appropriation, unobligated balances totaling $38.183 million are available for obligation in FY 1990. The sources of these funds are as follows:

- The unobligated balance of $37.951 million from the FY 1989 Research and Related Activities Appropriation which consists of: $37.000 million of funds available during FY 1989 for the replacement of the NRAO telescope at Green Bank, West Virginia, which were carried over pending completion of design studies necessary prior to construction; $56 thousand of small unobligated balances in each of the research directorates; and $895 thousand of funds available in the 1989 NSF appropriation for the International Institute for Applied Systems Analysis (IIASA). These funds have been set aside in the research directorates, whose disciplinary programs would be supported by the work proposed by IIASA pending completion of the proposal review.
- The $61 thousand unobligated balance from the FY 1989 Science and Engineering Education Activities Appropriation is carried over from small unobligated balances in each of the subactivities. This balance will be used to fund the activities planned in FY 1990.

A balance of $171 thousand from the United States Antarctic Appropriation remained unobligated at the end of FY 1989. This balance will be available for operations support during FY 1990.

Crosswalk from Current Plan to FY 1990 Estimates
(000)

	FY 1990 Current Plan New Obligational Authority	Carryover from FY1989	FY1990 Estimate
Biological, Behavioral and Social Sciences	$293,535	$170	$293,705
Computer and Information Science and Engineering	169,792	89	169,881
Engineering	200,221	137	200,358
Geosciences	375,006	194	375,200
Mathematical and Physical Sciences	557,006	37,314	594,320
Scientific, Technological and International Affairs	63,468	47	63,515
Science and Engineering Education	204,265	61	204,326
U.S. Antarctic Research	151,682	171	151,853

BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY
SHOWING DOLLAR AND PERCENTAGE CHANGES: FY 1991/FY 1990 (Dollars in Thousands)

	Actual FY 1989	Request FY 1990	Current Plan FY 1990 1/	Estimate FY 1991	Difference FY 1991/1990 Amount	Percent
BIOLOGICAL, BEHAVIORAL & SOCIAL SCIENCES						
Molecular Biosciences	$46,703	$51,380	$48,043	$51,963	$3,920	8.2%
Cellular Biosciences	55,532	60,580	57,326	63,075	5,749	10.0%
Biotic Systems and Resources	62,815	76,010	66,704	73,385	6,681	10.0%
Behavioral and Neural Sciences	44,825	48,280	45,843	49,058	3,215	7.0%
Social and Economic Science	30,873	33,220	32,259	35,490	3,231	10.0%
Instrumentation and Resources	36,571	40,030	38,460	43,229	4,769	12.4%
Science and Technology Centers	4,150	5,000	4,900	11,325	6,425	131.1%
Total, BBS	281,469	314,500	293,535	327,525	33,990	11.6%
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING						
Computer and Computation Research	21,169	23,673	21,981	24,280	2,299	10.5%
Information Robotics and Intelligent Systems	19,136	21,437	19,980	22,880	2,900	14.5%
Microelectronic Information Processing Systems	14,977	18,952	16,609	18,870	2,261	13.6%
Advanced Scientific Computing	55,586	71,689	62,830	62,580	(250)	-0.4%
Networking and Communications Research and Infrastructure	17,608	27,133	22,190	31,290	9,100	41.0%
Cross-Disciplinary Activities	17,437	21,416	19,636	24,030	4,394	22.4%
Science and Technology Centers	5,925	6,700	6,566	9,320	2,754	41.9%
Total, CISE	151,838	191,200	169,792	193,250	23,458	13.8%
ENGINEERING						
Biological and Critical Systems	34,067	39,920	39,431	36,130	(3,301)	-8.4%
Chemical and Thermal Systems	30,979	35,912	34,179	33,140	(1,039)	-3.0%
Electrical and Communications Systems	29,872	36,040	32,922	31,810	(1,112)	-3.4%
Mechanical and Structural Systems	23,039	26,778	25,282	24,410	(872)	-3.4%
Design and Manufacturing Systems	18,056	21,850	20,695	19,770	(925)	-4.5%
Engineering Centers	40,427	50,700	47,712	55,310	7,598	15.9%
Engineering Infrastructure Development	10,625	0	0	25,430	25,430	N/A
Total, ENG.	187,065	211,200	200,221	226,000	25,779	12.9%
GEOSCIENCES						
Atmospheric Sciences	98,577	109,440	104,097	120,119	16,022	15.4%
Earth Sciences	54,222	65,160	60,106	71,531	11,425	19.0%
Ocean Sciences	145,883	152,880	147,373	171,000	23,627	16.0%
Arctic Research Program	10,284	12,820	12,450	16,650	4,200	33.7%
Science and Technology Centers	943	1,000	980	4,425	3,445	351.5%
Total, GEO	309,909	341,300	325,006	383,725	58,719	18.1%
MATHEMATICAL AND PHYSICAL SCIENCES						
Mathematical Sciences	66,019	76,846	69,118	73,720	4,602	6.7%
Astronomical Sciences	89,224	96,018	91,647	100,700	9,053	9.9%
Physics	122,284	129,998	123,831	130,230	6,399	5.2%
Chemistry	96,745	103,428	97,945	103,350	5,405	5.5%
Materials Research	115,084	135,177	116,939	123,460	6,521	5.6%
Science and Technology Centers	13,947	14,833	14,536	27,040	12,504	86.0%
Major Research Equipment	500	0	42,990	63,000	20,010	46.5%
Total, MPS	503,803	553,500	[illegible]	621,500	64,494	11.6%
RESEARCH FACILITIES MODERNIZATION	0	0	[illegible]	20,000	310	1.6%
SCIENCE AND TECHNOLOGY CENTERS	0	20,000	0	0	0	0.0%

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

BUDGET SUMMARY OF OBLIGATIONS BY ACTIVITY AND SUBACTIVITY
SHOWING DOLLAR AND PERCENTAGE CHANGES: FY 1991/FY 1990 (Dollars in Thousands)

	Actual FY 1989	Request FY 1990	Current Plan FY 1990 1/	Estimate FY 1991	Difference FY 1991/1990 Amount	Difference FY 1991/1990 Percent
SCIENTIFIC, TECHNOLOGICAL AND INTERNATIONAL AFFAIRS						
Science Resources Studies	4,252	6,000	5,313	5,990	677	12.7%
Policy Research and Analysis	852	850	843	850	7	0.8%
Research Initiation and Improvement	22,932	26,740	26,030	32,150	6,120	23.5%
Industrial Science and Technological Innovation	19,052	21,460	20,046	22,930	2,884	14.4%
International Cooperative Scientific Activities	11,223	12,272	11,236	12,080	844	7.5%
Total, STIA	58,311	67,322	63,468	74,000	10,532	16.6%
PROGRAM DEVELOPMENT AND MANAGEMENT	91,286	104,000	96,383	102,500	6,117	6.3%
NSF HEADQUARTERS RELOCATION	0	0	0	5,500	5,500	0.0%
TOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,725,101	1,954,000	228,899	13.3%
Carryover 1989	0	0	37,951	0	(37,951)	-100.0%
TOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,763,052	1,954,000	190,948	10.8%
SCIENCE AND ENGINEERING EDUCATION						
Teacher Preparation and Enhancement	63,662	68,500	81,000	89,600	8,600	10.6%
Materials Development, Research and Informal Science Education	43,986	49,000	48,000	61,500	13,500	28.1%
Undergraduate Science, Engineering and Mathematics Education	27,999	30,000	34,000	50,000	16,000	47.1%
Research Career Development	30,980	38,000	36,900	44,900	8,000	21.7%
Studies and Program Assessment	4,500	4,500	4,365	5,000	635	14.5%
SUBTOTAL	171,127	190,000	204,265	251,000	46,735	22.9%
Carryover 1989	0	0	61	0	(61)	-100.0%
Total, SEE	171,127	190,000	204,326	251,000	46,674	22.8%
U.S. ANTARCTIC PROGRAM						
U.S. Antarctic Research Program	15,572	17,500	17,016	19,000	1,984	11.7%
Operations Support	88,497	102,200	99,370	110,000	10,630	10.7%
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704	30.3%
Subtotal	131,069	156,000	151,682	175,000	23,318	15.4%
Carryover 1989	0	0	171	0	(171)	-100.0%
Total, USAP	131,069	156,000	151,853	175,000	23,147	15.2%
OFFICE OF INSPECTOR GENERAL	0	0	2,560	3,000	440	17.2%
TOTAL, NATIONAL SCIENCE FOUNDATION	1,885,877	2,149,022	2,083,608	2,383,000	299,392	14.4%
Carryover 1989	0	0	38,183	0	(38,183)	-100.0%
TOTAL, NATIONAL SCIENCE FOUNDATION	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209	12.3%

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
BIOLOGICAL, BEHAVIORAL, AND SOCIAL SCIENCES					
MOLECULAR BIOSCIENCES					
Biochemistry	$13,479	$14,500	$13,843	$14,690	$847
Biophysics	14,349	15,940	14,700	15,600	900
Genetics	18,875	20,940	19,500	21,673	2,173
Total	46,703	51,380	48,043	51,963	3,920
CELLULAR BIOSCIENCES					
Cell Biology	15,771	17,368	16,106	17,233	1,127
Cellular Biochemistry	11,965	12,691	12,220	13,579	1,359
Developmental Biology	13,892	14,838	14,340	15,917	1,577
Physiological Processes	13,904	15,683	14,660	16,346	1,686
Total	55,532	60,580	57,326	63,075	5,749
BIOTIC SYSTEMS AND RESOURCES					
Ecology	9,955	12,430	10,684	11,784	1,100
Ecosystem Studies	23,478	27,330	24,400	26,881	2,481
Systematic Biology	12,719	15,920	13,720	15,020	1,300
Population Biology and Physiological Ecology	10,451	12,960	11,300	12,400	1,100
Biological Research Resources	6,212	7,370	6,600	7,300	700
Total	62,815	76,010	66,704	73,385	6,681
BEHAVIORAL AND NEURAL SCIENCES					
Anthropology	7,899	8,000	8,000	8,600	600
Language, Cognition and Social Behavior	9,643	10,200	9,600	10,300	700
Biological Basis of Behavior	11,321	12,950	12,000	13,028	1,028
Neuroscience	15,962	17,130	16,243	17,130	887
Total	44,825	48,280	45,843	49,058	3,215
SOCIAL AND ECONOMIC SCIENCE					
Economics	12,874	13,886	13,339	14,280	941
Geography	2,937	3,195	3,240	3,860	620
Sociology	3,724	4,170	3,960	4,340	380
Measurement Methods and Data Improvement	2,372	2,375	2,380	2,630	250
Political Science	3,785	3,980	3,860	4,240	380
Law and Social Sciences	1,917	2,107	2,060	2,350	290
Decision, Risk and Management Science	3,264	3,507	3,420	3,790	370
Total	30,873	33,220	32,259	35,490	3,231
INSTRUMENTATION AND RESOURCES					
Instrumentation and Instrument Development	16,593	18,100	16,000	16,600	600
Special Projects	17,728	19,430	20,000	23,979	3,979
Studies in Science and Technology	2,250	2,500	2,460	2,650	190
Total	36,571	40,030	38,460	43,229	4,769
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	4,150	5,000	4,900	11,325	6,425
TOTAL, BBS	$281,469	$314,500	$293,535	$327,525	$33,990

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
COMPUTER AND INFORMATION SCIENCE AND ENGINEERING					
COMPUTER AND COMPUTATION RESEARCH					
Computer and Computation Theory	$6,425	$6,719	$6,421	$6,890	$469
Numeric and Symbolic Computation	2,829	2,951	3,330	3,990	660
Computer Systems Architecture	3,098	3,595	3,100	3,210	110
Software Systems	6,076	6,870	5,870	6,130	260
Software Engineering	2,761	3,538	3,260	4,060	800
Total	21,169	23,673	21,981	24,280	2,299
INFORMATION, ROBOTICS AND INTELLIGENT SYSTEMS					
Knowledge and Database Systems	7,680	8,213	7,750	9,120	1,370
Robotics and Machine Intelligence	6,037	6,770	6,240	6,550	310
Interactive Systems	2,660	3,387	2,660	3,050	390
Information Technology and Organizations	2,759	3,267	3,330	4,160	830
Total	19,136	21,637	19,980	22,880	2,900
MICROELECTRONIC INFORMATION PROCESSING SYSTEMS					
Design, Tools and Test	2,987	3,295	3,119	3,620	501
Microelectronic Systems Architecture	2,669	3,087	2,840	3,240	400
Circuits and Signal Processing	3,416	3,783	3,560	3,820	260
Experimental Systems	4,087	6,080	4,900	5,700	800
Systems Prototyping and Fabrication	1,818	2,707	2,190	2,490	300
Total	14,977	18,952	16,609	18,870	2,261
ADVANCED SCIENTIFIC COMPUTING					
Centers	53,793	69,028	60,210	59,590	(620)
New Technologies	1,793	2,661	2,620	2,990	370
Total	55,586	71,689	62,830	62,580	(250)
NETWORKING AND COMMUNICATIONS RESEARCH AND INFRASTRUCTURE					
NSFNET	13,590	19,632	15,960	22,040	6,080
Networking and Communications Research	4,018	7,501	6,230	9,250	3,020
Total	17,608	27,133	22,190	31,290	9,100
CROSS-DISCIPLINARY ACTIVITIES					
CISE Institutional Infrastructure	14,946	18,928	17,143	20,540	3,397
CISE Instrumentation	2,491	2,488	2,493	3,490	997
Total	17,437	21,416	19,636	24,030	4,394
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	5,925	6,700	6,566	9,320	2,754
TOTAL, CISE	$151,838	$191,200	$169,792	$193,250	$23,458

1/ Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
ENGINEERING					
BIOLOGICAL AND CRITICAL SYSTEMS					
Bioengineering and Aiding the Disabled	$11,380	$12,570	$11,325	$12,280	$955
Environmental and Ocean Systems	5,292	5,575	5,430	5,900	470
Earthquake Hazard Mitigation	14,837	15,485	14,325	15,250	925
NEHRP Funds Transferred Pursuant to P.L. 101-130	0	0	2,000	0	(2,000)
Natural and Man-Made Hazard Mitigation	2,558	2,733	2,520	2,700	180
Total	34,067	36,363	35,600	36,130	530
CHEMICAL AND THERMAL SYSTEMS					
Chemical Reaction Processes	6,736	6,722	6,600	7,000	400
Interfacial, Transport and Separations Processes	7,624	8,973	7,900	8,775	875
Thermal Systems	7,807	7,989	7,550	8,145	595
Fluid, Particulate and Hydraulic Systems	8,812	9,028	8,615	9,220	605
Total	30,979	32,712	30,665	33,140	2,475
ELECTRICAL AND COMMUNICATIONS SYSTEMS					
Quantum Electronics, Waves and Beams	7,946	8,930	7,950	8,500	550
Solid State and Microstructures	9,030	9,472	8,850	9,400	550
Communications and Computational Systems	4,857	5,508	4,850	5,450	600
Engineering Systems	6,214	6,195	6,225	6,625	400
Emerging Technologies Initiation	1,825	2,733	1,835	1,835	0
Total	29,872	32,838	29,710	31,810	2,100
MECHANICAL AND STRUCTURAL SYSTEMS					
Dynamic Systems and Control	3,179	3,361	3,130	3,350	220
Structures and Building Systems	6,655	7,178	6,620	7,100	480
Materials Engineering and Tribology	7,123	7,406	7,000	7,540	540
Solid and Geomechanics	6,082	6,449	5,950	6,420	470
Total	23,039	24,394	22,700	24,410	1,710
DESIGN AND MANUFACTURING SYSTEMS					
Operations Research and Production Systems	4,689	5,256	5,000	5,710	710
Design and Computer-Integrated Engineering	6,021	6,549	5,940	6,325	385
Manufacturing Processes and Equipment	7,346	8,098	7,350	7,735	385
Total	18,056	19,903	18,290	19,770	1,480
ENGINEERING CENTERS					
Engineering Research Centers	37,175	44,315	42,575	50,070	7,495
Industry/University Cooperative Research Centers	3,252	4,675	3,860	5,240	1,380
Total	40,427	48,990	46,435	55,310	8,875
ENGINEERING INFRASTRUCTURE DEVELOPMENT					
Engineering Education	1,700	6,000	6,000	12,000	6,000
Human Resources Development	4,222	4,630	6,525	8,930	2,405
Physical Infrastructure Development	3,260	3,520	2,470	2,500	30
Special Studies and Analyses	1,443	1,850	1,826	2,000	174
Total	10,625	16,000	16,821	25,430	8,609
TOTAL, ENGINEERING	$187,065	$211,200	$200,221	$226,000	$25,779

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
GEOSCIENCES					
ATMOSPHERIC SCIENCES					
Atmospheric Sciences Project Support	$49,914	$55,230	$53,187	$63,409	$10,222
National Center for Atmospheric Research	43,693	48,250	45,290	49,930	4,640
Upper Atmospheric Facilities	4,970	5,960	5,620	6,780	1,160
Total	98,577	109,440	104,097	120,119	16,022
EARTH SCIENCES					
Earth Sciences Project Support	36,696	42,320	39,690	46,351	6,661
NEHRP Funds Transferred Pursuant to P.L. 101-130	0	0	1,000	0	(1,000)
Instrumentation and Facilities	12,568	15,200	13,850	18,450	4,600
Continental Dynamics	4,958	7,640	5,566	6,730	1,164
Total	54,222	65,160	60,106	71,531	11,425
OCEAN SCIENCES					
Ocean Sciences Research Support	70,915	74,660	72,935	88,585	15,650
Oceanographic Centers and Facilities	43,589	45,330	42,458	47,438	4,980
Ocean Drilling Program	31,379	32,890	31,980	34,977	2,997
Total	145,883	152,880	147,373	171,000	23,627
ARCTIC RESEARCH PROGRAM					
Arctic Research Projects	9,784	12,320	11,965	16,140	4,175
Arctic Research Commission	500	500	485	510	25
Total	10,284	12,820	12,450	16,650	4,200
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	943	1,000	980	4,425	3,445
TOTAL GEOSCIENCES	$309,909	$341,300	$325,006	$383,725	$58,719

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
MATHEMATICAL AND PHYSICAL SCIENCES					
MATHEMATICAL SCIENCES					
Classical Analysis	$5,807	$6,467	$5,970	$6,220	$250
Modern Analysis	5,779	6,464	5,960	6,210	250
Geometric Analysis	5,890	7,163	6,310	6,680	370
Topology and Foundations	7,036	7,870	7,240	7,550	310
Algebra and Number Theory	9,848	11,149	10,120	10,560	440
Applied Mathematics	8,134	9,204	8,300	8,700	400
Statistics and Probability	7,264	8,209	7,440	7,810	370
Computational Mathematics	4,737	5,854	4,908	5,220	312
Special Projects	11,524	13,666	12,870	14,770	1,900
Total	66,019	76,046	69,118	73,720	4,602
ASTRONOMICAL SCIENCES					
Astronomy Project Support	28,651	31,231	30,420	31,910	1,490
National Astronomy and Ionosphere Center	6,187	6,347	6,267	11,270	5,003
National Optical Astronomy Observatories	24,321	25,230	24,620	25,770	1,150
National Radio Astronomy Observatory	30,065	31,210	30,340	31,750	1,410
Total	89,224	94,018	91,647	100,700	9,053
PHYSICS					
Elementary Particle Physics	40,114	43,434	39,831	41,330	1,499
Nuclear Sciences	41,898	44,706	42,000	43,500	1,500
Atomic, Molecular, and Optical Physics	13,868	14,421	14,300	15,400	1,100
Theoretical Physics	16,616	17,084	17,400	18,700	1,300
Gravitational Physics	9,788	10,353	10,300	11,300	1,000
Total	122,284	129,998	123,831	130,230	6,399
CHEMISTRY					
Chemical Instrumentation	8,251	8,900	8,100	8,800	700
Organic and Macromolecular Chemistry	23,882	24,968	24,520	25,290	770
Physical Chemistry	28,454	29,840	29,060	30,480	1,420
Inorganic, Bioinorganic and Organomettalic Chemistry	15,959	16,630	16,250	17,170	920
Analytical and Surface Chemistry	12,719	13,540	12,950	13,660	710
Special Projects	7,480	9,550	7,065	7,950	885
Total	96,745	103,428	97,945	103,350	5,405
MATERIALS RESEARCH					
Materials Research Project Support	64,833	69,610	66,059	69,160	3,101
Materials Research Laboratories and Groups	34,218	36,197	34,550	36,900	2,350
National Facilities and Instrumentation	16,033	17,370	16,330	17,400	1,070
Total	115,084	123,177	116,939	123,460	6,521
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	13,947	14,833	14,536	27,040	12,504
MAJOR RESEARCH EQUIPMENT					
Major Research Equipment	500	12,000	42,990	63,000	20,010
TOTAL, MPS	$503,803	$553,500	$557,006	$621,500	$64,494

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

PROGRAM ELEMENT	(Dollars in Thousands) ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
RESEARCH FACILITIES MODERNIZATION					
Research Facilities Modernization	$0	$0	$19,690	$20,000	$310
SCIENCE AND TECHNOLOGY CENTERS					
Science and Technology Centers	0	20,000	0	0	0
SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS					
SCIENCE RESOURCES STUDIES					
Studies of Science and Engineering Resources	4,252	6,000	5,313	5,990	677
Total	4,252	6,000	5,313	5,990	677
POLICY RESEARCH AND ANALYSIS					
Policy Research and Analysis	852	850	843	850	7
Total	852	850	843	850	7
RESEARCH INITIATION AND IMPROVEMENT					
Individual & Group Support for Women and Minorities	4,211	5,950	5,682	11,550	5,868
Minority Institutional Development Support	10,630	10,790	10,548	10,800	252
EPSCoR	8,091	10,000	9,800	9,800	0
Total	22,932	26,740	26,030	32,150	6,120
INDUSTRIAL SCIENCE AND TECHNOLOGICAL INNOVATION					
Small Business Innovation Research	19,052	21,460	20,046	22,510	2,464
College and University Innovation Research	0	0	0	420	420
Total	19,052	21,460	20,046	22,930	2,884
INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES					
International Cooperative Science	11,223	12,272	11,236	12,080	844
Total	11,223	12,272	11,236	12,080	844
TOTAL, STIA	58,311	67,322	63,468	74,000	10,532
PROGRAM DEVELOPMENT AND MANAGEMENT					
Program Development and Management	91,286	104,000	96,383	102,500	6,117
NSF HEADQUARTERS RELOCATION	0	0	0	5,500	5,500
SUBTOTAL, RESEARCH AND RELATED ACTIVITIES	1,583,681	1,803,022	1,725,101	1,954,000	228,899
Carryover 1989	0	0	37,951	0	(37,951)
TOTAL, RESEARCH AND RELATED ACTIVITIES	$1,583,681	$1,803,022	$1,763,052	$1,954,000	$190,948

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
SCIENCE AND ENGINEERING EDUCATION					
TEACHER PREPARATION AND ENHANCEMENT					
Science and Mathematics Education Networks	$9,000	$10,000	$16,000	$23,000	$7,000
Teacher Enhancement	45,127	46,000	53,100	54,200	1,100
Presidential Awards for Excellence in Science and Mathematics Teaching	1,816	2,500	2,900	2,900	0
Teacher Preparation	7,719	10,000	9,000	9,500	500
Total	63,662	68,500	81,000	89,600	8,600
MATERIALS DEVELOPMENT, RESEARCH AND INFORMAL SCIENCE EDUCATION					
Applications of Advanced Technologies	5,986	6,500	6,300	6,500	200
Informal Science Education	15,000	16,000	15,700	19,000	3,300
Instructional Materials Development	18,500	21,500	21,200	31,000	9,800
Research in Teaching and Learning	4,500	5,000	4,800	5,000	200
Total	43,986	49,000	48,000	61,500	13,500
UNDERGRADUATE SCIENCE, ENGINEERING AND MATHEMATICS EDUCATION					
Instrumentation & Laboratory Improvement	16,000	16,000	15,800	23,000	7,200
Faculty Enhancement	3,000	3,000	2,900	4,000	1,100
Career Access Opportunities in S&T for Women, Minorities & the Disabled	5,000	7,000	11,300	15,000	3,700
Course and Curriculum	3,999	4,000	4,000	8,000	4,000
Total	27,999	30,000	34,000	50,000	16,000
RESEARCH CAREER DEVELOPMENT					
Graduate Fellowships	21,580	28,000	25,400	30,500	5,100
Minority Graduate Fellowships	2,400	3,000	4,500	5,400	900
Young Scholars	7,000	7,000	7,000	9,000	2,000
Total	30,980	38,000	36,900	44,900	8,000
STUDIES AND PROGRAM ASSESSMENT					
Studies and Analyses	4,500	4,500	4,365	5,000	635
Total	4,500	4,500	4,365	5,000	635
SUBTOTAL, SEE	171,127	190,000	204,265	251,000	46,735
Carryover 1989	0	0	61	0	(61)
TOTAL, SEE	$171,127	$190,000	$204,326	$251,000	$46,674

1/ Current Plan amounts exclude carryover unobligated balances from 1989.
See explanation of carryover 1989.

LEVEL OF FUNDING BY PROGRAM - CONTINUED

(Dollars in Thousands)

PROGRAM ELEMENT	ACTUAL FY 1989	REQUEST FY 1990	CURRENT PLAN FY 1990 1/	ESTIMATE FY 1991	DIFFERENCE
U.S. ANTARCTIC PROGRAM					
U.S. ANTARCTIC RESEARCH PROGRAM					
U.S. Antarctic Research Program	$15,572	$17,500	$17,016	$19,000	$1,984
Total	15,572	17,500	17,016	19,000	1,984
OPERATIONS SUPPORT					
Science Support	19,300	26,000	24,280	28,000	3,720
Operations and Maintenance	69,197	76,200	75,090	82,000	6,910
Total	88,497	102,200	99,370	110,000	10,630
MAJOR CONSTRUCTION AND PROCUREMENT					
Major Construction and Procurement	27,000	36,300	35,296	46,000	10,704
Total	27,000	36,300	35,296	46,000	10,704
SUBTOTAL, USAP	131,069	156,000	151,682	175,000	23,318
Carryover 1989	0	0	171	0	(171)
TOTAL, USAP	131,069	156,000	151,853	175,000	23,147
OFFICE OF INSPECTOR GENERAL					
Office of Inspector General	0	0	2,560	3,000	440
SUBTOTAL, NSF	1,885,877	2,149,022	2,083,608	2,383,000	299,392
Carryover 1989	0	0	38,183	0	(38,183)
TOTAL, NSF	$1,885,877	$2,149,022	$2,121,791	$2,383,000	$261,209

1/ Current Plan amounts exclude carryover unobligated balances from 1989. See explanation of carryover 1989.

WEDNESDAY, FEBRUARY 28, 1990.

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

WITNESS

D. ALLAN BROMLEY, DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT

Mr. **TRAXLER**. We want to welcome Dr. Bromley, the Director of the Office of Science and Technology Policy.

We note that the fiscal year 1989 appropriation for the Office was $1,574,000, with 12 FTEs. The 1990 estimate is $2,829,000 and 39 FTEs, and the 1991 request is $3,300,000 and 43 FTEs; and you are a growth industry. We are very pleased to take your statement. We will print it in its entirety in the record, and you may proceed in any fashion you wish.

OPENING STATEMENT

Mr. **BROMLEY**. Thank you very much, Mr. Chairman.

What I will do then is simply touch on a few highlights of my testimony and then respond to your questions.

Mr. **TRAXLER**. Please.

Mr. **BROMLEY**. I want to first of all thank you and Members for the opportunity that this provides for me to meet with you and tell you something about the Bush administration's science priorities, and specifically about the budget for the Office of Science and Technology Policy.

As I think all of you are aware, the office has undergone some substantial changes in the Bush administration; perhaps the most important one, from my parochial point of view at least, the fact that my position has been upgraded to that of Assistant to the President, and that means that I automatically sit in on Domestic Policy Council, Economic Policy Council, Space Council, and the other Cabinet council meetings and attend all the Cabinet meetings. This makes it certainly possible for me to inject matters of science and technology into a lot of discussions where previously, it simply wouldn't have happened.

I think also that the increased access that I now have to the White House and directly to the President—since I report directly to him—has certainly increased our ability to fulfill the mandate that you gentlemen gave to the Office in the 1976 legislation to provide a source of scientific and technological analyses and judgment to the President with respect to major policies, plans and programs of the government.

What I would like to emphasize to you, again, is that I think one of my major responsibilities is rebuilding bridges between my office and Congress, because they had not been as strong and as active as I think they should have been in the past. I have been undertaking a series of meetings, starting with staffs of various groups in both the House and the Senate, and those have been, I think, certainly very productive from my side, and what I am trying to do is to make the staff here feel that we are very much open to comments and discussions with them, as we move forward.

I want this to be a cooperative activity. One of the results, of course, of the increased stature that we have in the Executive Office of the President is that we have to cover a lot more ground now than we did in the past, and the first time, of course, in history of OSTP the President has nominated all of the four Presidentially-appointed, Senate confirmed Associate Directors that you provided for in the 1976 legislation.

The last two of those Associates Directors are in fact having their confirmation hearings at this moment, and I am very optimistic that they will be accepted. They will have major responsibility in the four areas of physical science and engineering, life science, policy and international science, and—something totally new for my office, and emphasizing the T part of OSTP—I have a very qualified Associate Director-designate for Industrial Technology.

We do that for two reasons. One, because I think industrial technology is terribly important for our nation in terms both of competitiveness and national security, and because I actually want to use this to send a real message to that community, that we do mean business and we are prepared to work with them.

That is a rather major change. And additionally, because one of the problems that the President has noted is that there was no direct channel for him to get input from the private sector, he has just recently, as you may have noted, created the President's Council of Advisors in Science and Technology. That is a 13-member group that I chair, and one that has a very distinguished cast of characters.

Three weeks ago this Saturday, the President met with this group for three hours at Camp David, and we had what I thought was a very effective meeting. From now on we will meet on a monthly basis and we will operate through a rather large number of panels. In addition to our activities of the kind that I have mentioned thus far, formulation of national policy and so on, we have the major responsiblity, as you know, of trying to coordinate and integrate science and technology programs across the entire spectrum of the Federal Government.

To that end, I have been working diligently since I got here to revitalize and restructure the Federal Coordinating Council for Science, Engineering and Technology. It has a somewhat unhappy acronym of FCCSET. But the FCCSET group with very strong support I may say from the Cabinet so that we have very high policy content there, and we will have committees then under FCCSET that will again draw from the deputy secretary and undersecretary level, so that commitment made in those committees will stick on behalf of the agencies.

One of the reasons that I am particularly taken with the potential of this activity is the success of our Committee on Earth Sciences during this past 18 months. They took the original budget proposals from seven different agencies in the global change area, pulled them together and massaged them.

And then when we brought those forward to OMB and subsequently to the President in the creation of the FY 1991 budget, the fact that they had been massaged in this peer fashion, and that the pieces had all been put together into a coherent fashion both OMB and the President found it very easy to consider this a coherent national program, and you see this reflected in a 57 percent proposed increase for work in this important area of global change.

During the coming years I would like to see similar activity in areas like high-performance computing, material science, biotechnology, and in particular, human resources and education, because it has become very clear that there is vastly more educational activity under way, funded by you gentlemen, than appears anywhere on the record. And as a first order of business, we want to sort that out, and then get some coherence in the agency programs, established within the framework of their own missions, into a national program responding to the President's initiative, and initiatives that many of you have played key roles in.

I consider that it has been important to spend a lot of my time in this past several months since I have been here to develop a much better working relationship between my office and OMB. I have always understood that if you really have the money, you have a large hand in policy, and so it was important to make some common cause. I am happy to be able to report to you this morning, gentlemen, that we in fact have made common cause with Dick Darman, and it, I think, has already proven to be a very effective collaboration, and working relationship, in pulling together the 1991 budget. I look forward to it being much better, and to more extensive collaboration as we move forward.

The goal here is to have OMB and OSTP staff collaborate in all stages of the budget preparation, so that we do not come in at the end and try to figure out what the prospect you asked for in the past, across the government, is in various science and technology areas. We will have helped to build that from the beginning, will know what it is and how coherent it is.

We will start, then, using this FCCSET mechanism to bring the agencies together. That I think is a very important initiative.

One of the weaknesses of the FCCSET mechanism, however, has always been that there was no provision for bringing in private sector input. But now that we have the President's Council, that reports directed to him, and since I chair both FCCSET and PCAST, it is my responsibility and my opportunity to bring panels from the private sector brought together under PCAST and intragovernmental groups under FCCSET together so we get that private sector input. It is very important in a number of areas that I have just mentioned.

To give you just a quick survey of how we operated this year, early in this past budget cycle OMB surveyed areas of R&D across the agency spectrum and asked the agencies in selected areas—where we wanted to do crosscuts—to provide us with numbers from their budget on the topic of the crosscut.

This was the first time we did this, and so I have to admit to you that the numbers we got are not nearly as hard as I would like them to be, or as hard as they will be next year. But at least we got sort of a tour of the horizon so we could see what was going on in the operation.

Then later in the year OSTP participated in the OMB budget hearings with the agencies, and the OMB Director's reviews, Director Darman was very generous and very cooperative and invited me to sit in on virtually all the hearings that had anything to do with science and technology, and as the final stage in this—as you know, this was a different budget process this year than any we have seen for quite some time with the A and B type categories—for those things that we weren't able to resolve, between OMB and OSTP and the agencies, of course the court of final arbitration was with the President. Mr. Darman and I, together with the agency heads involved, made the pitch to the President. The agency people involved had the chance to make the best case they could, and we either supported it or didn't, as we felt appropriate, and then the President made the decision.

That is what is represented by the science and technology aspect of things in the budget that we have sent—that the President has sent forward to you.

With respect to our own office, to OSTP, as you noted, Mr. Chairman, the 1991 request for OSTP is $3.3 million; it provides for the four hopefully then-confirmed Presidentially-appointed Associate Directors. Together with a relatively small cadre of assistant directors, policy analysts, and a total of 39 full-time members, and 43 FTEs.

I think that the staffing will allow us to reduce very substantially the number of detailees that we have. It is my goal to eventually get rid of the detailees except in special conditions where we need specific help when we are tackling a particular project that one of the Congressional committees may have assigned to us and where we need special expertise or something of that sort.

This budget request is 16.7 percent above that currently appropriated for fiscal year 1990, but I would emphasize to you, sir, that 4.8 percent of that increase is earmarked, right off the top, to support the President's Council of Advisors. That is a totally new activity as far as OSTP is concerned.

I think that you might be interested to know that just in the recent past, to give you a feeling for the kind of thing we have been doing for the Congress in response to specific requests, I would note that we just sent up one report on analysis of the balance between defense and non-defense research and development.

A second report where we had been asked to do an analysis of the Department of Education and the NSF activities in science and mathematics, engineering, education, and tried to make some recommendations for approving the coordination is also finished. I think not only have we made the recommendations to you—that report is coming up, I think today—but in fact, we have got a lot of them implemented already, so that a study done at your request has provided a real catalyst in getting those agencies to work together much better than they had been.

Third, we have been asked to provide a statement on the principal scientific questions that are outstanding in global change research—areas that need greater attention by the Congress. We are working on that and will have it to you at the requested date.

And by October of this year, we will have for you the first of the series of biennial reports that the Armed Services Committee has requested from us on the state of national critical technologies. We have been asked to merge the lists of critical technologies from Commerce and Defense, and then really present a case for why we picked those we kept, where we stand worldwide, what needs to be done to keep us in a competitive mode.

Given this kind of workload, together with the other things that we do for other groups within the White House—I would just mention, for example, that I chair the Domestic Policy Council Working Group on Global Change. One of my associate directors, Dr. Wyngaarden, chairs the Working Group on Biotechnology for the Competitiveness Council, and when my two new associate directors get into place, there are a number of such working groups just waiting for them.

Given the work that we have under way, we have a very full plate. I believe that the funding level that the President has requested for us enables us to fulfill the requirements that have been placed upon us, and I would simply say that, gentlemen, that given the breadth of our activities and the leverage that we can have in terms of coordinating and integrating programs across the Federal Government, I would like to suggest that this is one of the most cost-effective investments that you can make in science and technology activity in terms of effective expenditure of the $71.2 billion that we are talking about in the 1991 budget.

So with that, Mr. Chairman, let me simply stop and be prepared to respond to your questions.

[The prepared statement and biography of D. Allen Bromley follow:]

STATEMENT
by
D. Allan Bromley
Director, Office of Science and Technology Policy
Executive Office of the President
Before the Subcommittee on Veteran's Administration,
HUD-Independent Agencies
United States Congress

Mr. Chairman:

Thank you for giving me the opportunity to present the Administration's views on science priorities and the Administration's FY 1991 budget request for the Office of Science and Technology Policy. In doing so I will discuss how my office participates in the development of science priorities and how the Administration's proposals for the nation's science, technology, and space programs support our national goals.

As most of you are aware, The Office of Science and Technology Policy has undergone a number of changes in the Bush Administration. One important change is my appointment as Assistant to the President for Science and Technology, concurrent with my confirmation as Director of OSTP. This upgraded position for the Science Advisor reflects the increased importance of science and technology in the Bush Administration and has brought an expanded role and responsibilities for myself and the OSTP staff within the Executive Office of the President. These expanded responsibilities include my membership on the Domestic Policy Council, the Economic Policy Council, the Space Council, the Council on Competitiveness, and a close working relationship with the National Security Council and the Office of Management and Budget.

As specified by the National Science and Technology Policy, Organizations, and Priorities Act of 1976 (P.L. 94-282) that created OSTP, a major function of our office is to provide "a source of scientific and technological analysis and judgement for the President with respect to major policies, plans and programs of the federal government." My increased access and direct participation in the policy-making process within the White House has greatly increased OSTP's ability to fulfill this responsibility. I am directly involved in briefing the President on the scientific and technological components of national and international policies.

As a result of these expanded activities, OSTP staff members must cover far more ground than in the past. They interact on a daily basis with other units throughout the Executive Office of the President to ensure that considerations of science and technology are taken into account in policy deliberations. The staff has been upgraded and expanded. For the first time in OSTP's history, the President has nominated for Senate confirmation all four of the Associate Directors called for in P.L. 94-282. These four distinguished individuals will have responsibilities in physical science and engineering, life science, industrial technology, and policy and international science. As an example of the role that they will play, Dr. James Wyngaarden, OSTP's Associate Director for Life Science, heads the Biotechnology Working Group of the Council on Competitiveness chaired by the Vice-President.

My new responsibilities and the expanded and revitalized role of OSTP mean that issues of science and technology are well represented in the policy-making process of this Administration. In addition, however, the President has recently established a new, high-level advisory group of twelve distinguished scientists and engineers from the private sector that reports directly to him. The President's Council of Advisors on Science and Technology (PCAST), which I have the honor to chair, recently held its first meeting, hosted by the President at Camp David. I anticipate that PCAST will meet once a month and will establish a series of panels to focus on specific problem areas.

In addition to OSTP's roles in participating in the formulation of national policy on issues that involve science and technology, and providing access to authoritative science and technology advice, OSTP is also directed in P.L. 94-282 to coordinate Federal science and technology activities and to resolve science and technology policy issues that affect more than one agency. The primary mechanism for this is the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET), which I chair and that I am in the process of restructuring and revitalizing. As part of this restructuring, I intend to reorganize the FCCSET Committees so that they span the spectrum of science and technology in a more appropriate manner.

I anticipate that there will be occasions for interaction between PCAST panels and the reorganized FCCSET Committees, perhaps by holding joint meetings, so that Federal science and technology activities can take advantage of the experience of the private sector. An example of the role that I think FCCSET committees can and should play is provided by the Committee on Earth Sciences, which over the past year has developed a focused, coordinated, multi-agency program of research on global change and to which the President has responded by proposing a budget increase for FY 91 of 57 percent, to over $1 billion.

OSTP/OMB COOPERATION

On budget matters, I have worked closely with Richard Darman and OSTP and the Office of Management and Budget (OMB) staff have interacted closely in the development of science and technology budgets. Let me describe to you this developing interaction, which I believe is extremely important in the priority-setting process that goes into making up the Federal budget requests. As you know, this year this process has resulted in the President proposing a record total of $71 billion for research and development for FY 91, including a 12 percent increase in civilian R&D, which is impressive in the face of the current austere U.S. budget climate.

The entire outlook of the Bush Administration emphasizes investments in the future while -- at the same time -- maintaining commitments to the past and present. As an Administration we believe that one of the most effective ways of investing in our future is by supporting research and development in science and technology. Thus, the President has asked that there be a close co-operation between the Office of Science and Technology Policy, the Federal R&D agencies and the Office of Management and Budget in developing this Administration's R&D budget. This should insure that the Administration's proposals to Congress have a sound science and engineering underpinning and represent the most efficient and effective allocation of funds for the support of the Federal R&D enterprise.

We are planning to ensure that the first step in this close interagency co-operation will take place in the FCCSET council working groups. Here agency program officers with the guidance and advice of both OSTP and OMB staff will help co-ordinate the individual agency R&D programs to eliminate duplication and to ensure that all important areas of R&D in specific disciplines are, in fact, supported. The National High Performance Computing program and the U.S. Global Change program are two of the best examples of how this process has the potential to work. In the coming year other areas, such as materials R&D, that are supported by almost all of the R&D agencies will be reviewed in the same manner.

Then, during the summer months when these agencies are preparing their new budget proposals for presentation to the President, both OSTP and OMB staff will be available to the agency heads and their staffs to review the focus and content of individual agency programs required to carry out the agency missions. Finally, in the fall when all of the agency budget proposals are presented to the Administration, as OMB conducts its review, OSTP will have the opportunity to jointly evaluate and prioritize the different agency programs in light of urgent national needs and Administration policy. This process was started this past fall and we in OSTP and OMB expect the process to proceed even more smoothly this coming year.

To give you some feeling for the way our two agencies interacted this past year, let me describe briefly a few of the measures we set in place for future budget discussions. Early in the year, OMB surveyed areas of R&D commonly funded by the various R&D agencies; and then OMB requested that these agencies provide us with the funding levels for each activity identified in these areas. Since this was the first year we carried out this exercise, the data we gathered is not as 'hard' as we would have liked but we expect it to be more well-defined next year. After the data collection, agency personnel met with OMB staff for 'budget hearings' on these programs. OSTP participated in these hearings, as it did in the traditional Fall OMB 'Director's Review'.

At Director's Review, R&D programs and funding levels were examined to determine an optimum allocation of funds across the R&D agency budgets. I participated in virtually all of the hearings related to science and technology. This latter determination was very tough, since nearly all of the agency budget proposals were excellent and worthy of support. Unfortunately, the available budget resources would not -- nor I suspect will they ever -- stretch to cover all of these efforts. However, several general, quite simple guiding principles were applied.

First, support is required for all programs that address national needs and national security concerns. Examples would be, the Federal environmental clean-up effort, scientific research to address the global climate change issues, a pre-eminence in space and adequate support for the defense technology base. Implicit in this, I might add, we considered the balance of R&D funding for civilian versus defense needs.

The second guiding principle was the adequacy of support for basic research which, really, is the well-spring of all our future scientific and technological progress. In evaluating the agency programs, a concerted effort was made to ensure that 'small science' funding received the highest priority in the final individual agency programs. Finally, we examined the R&D budgets to insure that the level of funding for the scientific infrastructure and facilities in this country will maintain our scientific pre-eminence. Large facilities such as telescopes, synchrotrons, and particle accelerators are necessary for state-of-the-art research to continue. Although many may call these 'mega-projects', once built they service thousands of scientists and make possible a scientific understanding of the world and universe in which we live. They are essential for the health of our R&D enterprise.

The final step in preparing the Administration's budget is a series of meetings with the President. Dick Darman and I with the Cabinet Secretaries and other R&D agency heads sat down with the President to resolve the overall budget priorities in line with available budget resources. The very high priority the President accorded to Science and Technology is reflected in the fact that in his budget proposal to Congress, the chapters on research and development are preceded only by a chapter on increasing the national savings rate.

RECENT OSTP ACCOMPLISHMENTS

In the past year, the Office of Science and Technology Policy has been engaged in a number of activities designed to increase the contribution of science and technology to improved economic competitiveness and a strong national defense. Although many of these activities are being reorganized to reflect ongoing changes in the office, our future efforts will build on what has been done in the past.

The following descriptions touch only on some of the highlights of recent OSTP activities. A more thorough description can be found in the OSTP Budget Justification to Congress: "Summary of Accomplishments in FY 1989 by the Office of Science and Technology Policy."

In the area of international science and technology, OSTP has sought to ensure that science and technology become more integral parts of U.S. foreign relations and that science and technology issues are adequately considered in the development of foreign policy. OSTP has worked closely with the National Security Council, the State Department, and appropriate U.S. government technical agencies, as well as the nation's scientific and engineering communities, to plan, coordinate, and follow up on state visits and summits. In addition, OSTP has sought to encourage international participation in a number of large, world-class science projects currently under development, including the Superconducting Super Collider, Space Station Freedom, and the human genome project. Finally, OSTP has helped to coordinate and has participated in a number of multilateral and bilateral efforts to improve the infrastructure for science and technology around the world and to strengthen science and technology cooperation.

OSTP is also involved in the application of science and technology to support national security. For example, OSTP participates in efforts aimed at resolving critical scientific and technical issues and helps draft position and issue papers for use by the National Security Council, the Office of Management and Budget, and other participating agencies. The Director of OSTP is also assigned the responsibility for managing the nation's telecommunications resources during wartime and non-wartime national crises and emergencies. OSTP also recently assisted the National Security Council in redefining the President's policy on U.S. export controls.

Through my membership on the Space Council, OSTP plays a major role in reviewing and developing U.S. space policy. In the past, OSTP has also worked closely with NASA and other agencies on developing policies toward the National Aerospace Plane, Space Station Freedom, and NASA's space sciences program.

In the life sciences, OSTP has begun to plan and coordinate government-wide initiatives for the Decade of the Brain, which has been established by Congress and the President to recognize the dramatic increases in knowledge about the brain and its disorders and the formidable challenges of the future. OSTP has also been engaged in activities involving biotechnology and the human genome project.

Last year, it was my pleasure to recommend to the President the awarding of 27 National Medals of Science and Technology for distinguished achievement in mathematics, science, engineering, and technology and 112 Presidential Awards for Excellence in Science and Mathematics Teaching to the nation's top science and mathematics teachers.

Finally, OSTP has been working with the Office of Presidential Personnel to identify highly qualified candidates for a range of top-level science appointments.

FEDERAL R&D BUDGET

"The budget's chief emphasis is on investment in the future," according to President Bush, and that emphasis finds strong affirmation in the Administration's support of science and technology in the President's 1991 budget. Altogether, the budget proposes a healthy increase of 7 percent in the conduct of both civilian and defense R&D by the federal government. Even more encouraging to me is the distribution of that funding. The Administration's proposals would increase civilian R&D 12 percent, from the $23.8 billion that was enacted in FY 1990 to $26.7 billion in FY 1991. Basic research would go up about 8 percent, from $11.4 billion to $12.4 billion. At a time of declining real defense expenditures, proposed defense R&D would rise by 4 percent and defense basic research would go up by 5.9 percent. As evidenced by President Bush's first budget, science and technology are going to be major and ongoing concerns of this Administration.

Altogether, the total conduct of R&D, both civilian and defense, would rise to $68.1 billion. Adding $3.1 billion for the construction, repair, and modernization of R&D facilities brings the total proposed federal support for R&D to $71.2 billion. This amount is 5.1 percent of the total budget for FY 1991 and 1.3 percent of the U.S. gross national product. In FY 1990, the corresponding percentages were 5.0 percent of the total budget and 1.2 percent of GNP.

This year's budget proposals have the effect of changing the proportions of civilian and defense R&D funded by the federal government. During the 1980s, defense R&D rose much faster than civilian R&D, reaching a peak of 69 percent defense and 31 percent civilian in 1986 . Since 1986, the ratio of civilian R&D to defense R&D has been growing steadily, and in FY 1991 civilian R&D is projected to be 39 percent of the total conduct of federal R&D.

PRIORITIES

The Office of Science and Technology Policy is charged with reviewing and coordinating federal R&D that cuts across the missions of more than one federal agency and with providing advice to the President on issues of science and technology policy that affect national and international policy. In light of these responsibilities, OSTP has defined several areas that will receive major emphasis in the coming year.

Basic Research

Basic research provides a continuing flow of fundamental new knowledge, and federal support for basic research is an essential investment in the nation's scientific and technological future. Our country is unique in the extent to which our universities both conduct the research that expands the base of fundamental scientific knowledge and simultaneously prepare future generations of scientists and engineers to use that knowledge in an innovative and creative fashion.

This university-based, individual-investigator and small group research still constitutes the heart of our science and technology enterprise. Funding for this research must be protected to maintain the diversity and vitality of American science and technology.

A significant problem has arisen, particularly in the National Institutes of Health and the National Science Foundation, where the fraction of excellent, peer-reviewed, new proposals from young investigators just beginning their academic careers has fallen significantly, dropping to below 30 percent for the first time in the postwar period. The discouragement caused by a lack of funding is particularly unfortunate at a time when the nation has a very serious need to recruit more young people into such careers.

The problem results, in substantial measure, from the fact that agencies such as NIH and NSF have responded in the past to urgent and reasonable recommendations that grants be made on a multiyear basis and that individual grants be increased to reflect the rising costs of doing research. The corresponding "outyear mortgages" now limit the number of new proposals that can be approved. A contributing factor is the demographic fact that the number of young scientists competing for such support continues to grow at a rate exceeding that of the available resources.

The federal government also supports basic research through construction of the large, expensive research facilities that are essential to progress in areas ranging from space sciences to particle physics to materials engineering. Large facilities are important not only for academic research but also for industry-oriented research. OSTP will work to ensure that a balance is maintained between the demands of these large facilities and those of individual investigators.

Science and Technology for Economic Growth

Our ability as a nation to commercialize scientific and technological innovations effectively is a major factor in assuring our long-term economic growth, industrial competitiveness, and national security. The United States spends more on research and development than does any other country in the world. We must continually assess the role of government and industry in the technology commercialization process to ensure that we realize the full potential of this public and private investment. Indeed, defining new relationships between the public and private sectors to achieve this goal will be a major challenge of the 1990s.

A prerequisite for our future national well-being is a strong manufacturing sector. Our national policy toward technology has the primary underlying objective of encouraging this manufacturing base--particularly in the high technology end. In addition, the nation needs a better working relationship between government and industry and an improved climate for the formation of private sector R&D consortia. The sophistication and capital-intensive nature of modern technology require new ways of increasing cooperation between government and industry and of fostering communication on long-term technology goals.

OSTP plans to focus attention on several broad areas of advanced technology, including information technology, biotechnology, and materials science and engineering. Such "enabling" technologies, have application in a broad range of commercial sectors; however, no single company may be able to capture sufficient return to justify the required investment to develop the technology independently.

Advanced technologies cover the spectrum from basic research to engineering development in a broad range of fields. For purposes of illustration, the areas of information technology and materials science and engineering will be highlighted.

Information technology covers all aspects of computing, computer networks, and computer-aided design, engineering, and manufacturing. High-performance computing, while still a relatively small component of the overall industry, holds particular promise as a high-leverage technology that could expand dramatically in the future. A national computing network, ultimately linking research institutions, businesses, schools, and homes, will have very strong leverage on the rest of our economy.

Materials include the basic components of our industrial civilization, from ceramics, semiconductors, superconductors, and metals to polymers and composites. Important new insights into the nature of materials and new abilities to create materials, in some cases on an atom-by-atom basis, are ushering in an age of "tailored" materials that will have a wealth of everyday applications. OSTP intends to raise the visibility of this critical area of R&D.

Specific concerns in the area of science and technology policy and its implementation on which OSTP has and will continue to focus are:

- Refining our technology policy to establish guidelines for future federal R&D investments.
- Catalyzing state and local activities in industrial competitiveness to obtain maximum leverage for Federal funds.
- Fostering an effective three-way partnership involving industry, academia, and government.
- Improving the technology transfer process from Federal laboratories to the private sector.
- Encouraging the development and application by the private sector of critical technologies that exert strong leverage on the U.S. manufacturing sector and other sectors of the U.S. economy.

- Working to ensure an adequate flow of well-trained professionals in mathematics, engineering, and science.

Science and Technology for National Security

America's scientific and technological strength provides the qualitative edge that has long ensured our security and that of our allies. OSTP will continue to interact closely with the Department of Defense in providing advice to further advances in defense technology.

Particularly in times of international uncertainty and change, as noted above, a strong research and technology base is critical to promote investigation into promising new technologies and to guard against technological surprise from potential adversaries. OSTP is keenly interested in ensuring healthy levels of investment in critical and cutting-edge technologies central to tomorrow's defense.

Many of these technologies also have commercial applications. For example, they are integral to the development of the National Aerospace Plane, an aircraft designed to take off and land on a normal runway and fly through the atmosphere and into orbit at hypersonic speeds. The NASP program has also contributed to these technologies, generating important advances in composite materials and fluid dynamics.

The dramatic changes under way in Eastern Europe presage changes in the international environment and in the security needs of the West. The development and application of technology to support changing defense and foreign policy requirements in such areas as arms control verification technologies, intelligence collection, analysis and protection, and command, control, and communication capabilities are key OSTP concerns.

Life Sciences

The life sciences have made enormous progress during the last decade, yet they still represent a frontier with major advances already on the horizon that will dramatically enhance our quality of life. While research into diseases such as AIDS captures much attention, many other areas of investigation will also have a sweeping impact on our population: e.g., efforts to understand and ameliorate the effects of aging.

President Bush has designated the 1990s as the Decade of the Brain to focus needed public and scientific attention on the multidisciplinary efforts required to continue our progress in understanding mental illness, addictive disorders, and treatments for diseases that affect the brain. OSTP will be coordinating the activities of the individual federal agencies responding to this new initiative.

Global Change

Global change is one of several issues that highlight the increasingly interdisciplinary nature of science. At the federal level, this interconnectedness calls for an increasing number of R&D programs that involve different agencies and scientific specialties. The degree of success of the global change R&D program in predicting atmospheric temperatures, for example, will depend on effective communication between these specialties.

As our depth of knowledge increases, effective communication among scientists in different disciplines becomes ever more critical. OSTP will continue to play an important role in facilitating the necessary cross-fertilization among scientific communities.

The global change area is one where the effectiveness of the FCCSET mechanism has been demonstrated in striking fashion by the activities of FCCSET's Committee on Earth Sciences. This Committee has carefully coordinated and integrated the activities of eight federal agencies into a national research plan aimed at greatly improved understanding of the phenomena underlying global change.

Because global change is truly an international matter demanding international resolution, and because the President has made it clear that in this area--as in all others -- U.S. national policy must be based on sound science and sound economics, the President will host an international White House Conference here in Washington on April 17-18 of this year that will bring together the three senior government officials in science, economics, and the environment of each of the participating countries. The goals of the conference will include sensitizing these three communities to each other's activities, focusing on the gaps and uncertainties in current scientific and economic understanding, improving the analytic tools and data required to address problems of global change, and developing at least an initial framework for international research that draws on the resources, expertise, and data of all of the participating countries (this framework will parallel, in part, the national plan developed by the Committee on Earth Sciences).

International Science and Technology

The results of basic research have always been a global resource adding to the knowledge base and ultimately to the economic prosperity of all nations. While the social rate of return on investment in basic research is very high, benefits do not accrue only to sponsoring countries or governments but rather to the world at large. This being the case, where possible, nations need to coordinate planning and support for basic research, as in the above example of global change. Coordination is especially needed for projects that require extraordinary financial commitments, such as the Superconducting Super Collider, Space Station Freedom, and mapping of the human genome, and that involve science and engineering talent from many nations.

OSTP is developing a framework for dealing effectively and comprehensively with the challenges of coordinating science and technology on a global scale. This comprehensive approach will be addressed within the FCCSET structure. Existing bilateral science and technology relations with countries and regions such as Japan and the European Community will play an important role in this effort, as will emerging cooperation with the Soviet Union, Eastern Europe, and developing countries.

Science, Mathematics, and Engineering Education

Education at all levels needs to be revitalized. This revitalization involves not only the training of our scientists, engineers, and technical workforce but also the education of a population sufficiently literate in science and technology to deal with the social issues arising from rapid scientific and technical change.

Achieving such a goal will require a broad-based approach involving businesses, academia, educational organizations, and State and local governments. For example, businesses are playing an increasingly important role in the training and retraining of our workforce. Junior colleges and technical schools provide a means of upgrading the skills of our youth and workforce. And last but not least, the precollege level is where life-long interests in science and mathematics are aroused, if they are to be aroused at all.

Through FCCSET, OSTP is developing a framework for interagency coordination and collaboration for mathematics, science, engineering, and technology education. The goal will be to develop an effective and appropriate role for the Federal government in support of the states, localities, and universities as they reform science and technology education. In order for this new FCCSET committee to be effective, it will be necessary that the Department of Education (DOEd) become a member of the FCCSET Council. OSTP is currently working with DOEd and the Executive Office to develop the appropriate means to achieve this end.

Conclusions

Though the Administration's FY 1991 science and technology budget covers a wide range of R&D activities, several underlying themes unify the Administration's science and technology policy:

- The first is to preserve the initiative, independence, and creativity of American scientists through a stable multiyear pattern of funding for basic research and continued real growth in federal R&D funding.
- The second is to foster a more efficient and effective coupling between R&D and commercialization efforts.

- The third is to ensure that the best scientific advice is an integral part of all policy decisions on the environment.
- The fourth is to contribute to international cooperation through international support of large science projects such as the Superconducting Supercollider and the Space Station, along with international cooperation on a wide range of other scientific endeavors.
- Finally, a key goal is to improve national literacy in science and mathematics and meet future requirements for trained people in science and engineering. This is essential for our future economic prosperity in an increasingly technological and competitive world.

OSTP BUDGET SUMMARY

The total FY 1991 budget request of $3,300,000 for the Office of Science and Technology Policy (OSTP) will support an estimated 39 professional staff and support members.

The FY 1991 request provides for four confirmed Associate Directors -- the full number authorized in the 1976 enabling legislation. The four areas of responsibilities are: policy and international science and technology; industrial technology; life science; and physical and engineering sciences. In addition the FY 1991 request will provide for a small cadre of Assistant Directors and Senior Policy Analysts to assist the Associate Directors. The professional staff will be generalists, rather than specialists. This is essential, given the number of issues addressed by OSTP, and the changes in emphasis from year to year. This staffing assumes use of detailees only under unusual circumstances where no other alternative is available.

The FY 1991 request includes $135,000 for support of the President's Council of Advisors on Science and Technology (PCAST): $60,000 for the salary of the Executive Director, $15,000 for printing costs for reports generated by PCAST; and $60,000 for travel and subsistence for members of PCAST. The PCAST will be a very active group, with monthly plenary meetings, and an extensive subcommittee, panel and working group substructure. This will entail significantly increased costs from previous years.

The Budget request for FY 1991 is 16.7-percent, or $471,000, above that currently appropriated for FY 1990. However, 4.8-percent of the increase, or $135,000, is in support of the President's Council of Advisors for Science and Technology. The request provides a base of support which will allow OSTP to fulfill its increased responsibilities for coordination of the R&D policy of the Administration. This essential level of coordination is highly labor intensive, and should not be delegated outside the Executive Office. Let me summarize the existing responsibilities of OSTP described above:

- Direction of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). This requires an intensive level of participation, coordination, and guidance by OSTP staff in the numerous working groups of the various FCCSET committees.
- Interagency coordination, under FCCSET, of science and technology issues to be incorporated in negotiated agreements with foreign countries.
- Recommendations to the President on current major issues of science and technology policy; direction of, and participation in, interagency coordination of such issues, as appropriate. These activities require a high level of participation and interaction by OSTP in the numerous coordinating groups within the Executive Office of the President.
- Anticipation of new science and technology issues, or other issues with a significant science and technology component; advice to the President and initiation of interagency coordination on such issues, including technical findings or other actions, as appropriate.
- Coordination of the President's Council of Advisers on Science and Technology findings with interagency findings in appropriate areas of concern to the President and his advisors.
- Coordination with the Office of Management and Budget of the Administration's Budget request to Congress for science and technology.
- Preparation of reports, in accordance with legislative direction, including for 1990:

  A. Analysis of the balance between Defense and Non-Defense Research and Development.

  B. Report detailing the steps that the Department of Education and the National Science Foundation are taking to cooperate more readily on improving the coordination of math, science and engineering education, and

  c. Report describing OSTP views on the principal scientific questions in global change research, that are in greatest need of attention by the Congress; and how the existing Interagency Committee on Earth Sciences research strategy plans to answer these questions.

Given the high workload expected for FY 1991 and beyond, the requested level of support is fully in keeping with current budgetary constraints. In view of the significant leverage that can be exerted by coordination of science and technology policy within the Executive Office on the overall coherence and effectiveness of the research and development conducted within this nation. I believe that this is one of the most cost-effective program that Congress can support.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

D. ALLAN BROMLEY

D. Allan Bromley is Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. He is on leave from his former position as Henry Ford II Professor of Physics at Yale University, where he was founder and Director of the A.W. Wright Nuclear Structure Laboratory.

One of the world's leading nuclear physicists, he has carried out pioneering studies on both the structure and dynamics of nuclei and is considered the father of modern heavy ion science, one of the major areas of nuclear science. He has also played major roles in the development of accelerators, of detection systems, and in computer based data acquisition and analysis systems. An outstanding teacher, over the past two decades his Laboratory at Yale graduated more Ph.D.s in experimental nuclear physics than any other institution, worldwide. He has published over 450 papers in science and technology as well as edited eighteen books and has received numerous honors and awards, including the National Medal of Science.

For more than two decades, Dr. Bromley has been a leader in the national and international science and science policy communities. As chairman of the National Academy's Physics Survey in the early 1970s, he contributed in a central way to charting the future of that science in the subsequent decade. As president of the American Association for the Advancement of Science, the world's largest scientific society, and of the International Union of Pure and Applied Physics, the world coordinating body for that science, he has been one of the leading spokesmen for U.S. science and for international scientific cooperation.

Prior to his present appointment, Dr. Bromley served as a member of the White House Science Council throughout the Reagan Administration and as a member of the National Science Board in 1988-1989. As the U.S. chairman for both the Gandhi-Reagan Indo/U.S. and the Sarney-Reagan Brazil/U.S. Science and Technology Initiatives, he led four Presidential missions to conduct negotiations for bilateral cooperation in science and technology.

Born in Westmeath, Ontario, Canada, he received the B.Sc. degree with highest honors in 1948 in the Faculty of Engineering at Queen's University, Ontario, Canada. He received the M.Sc. degree from Queen's University in 1950 and the Ph.D. degree from the University of Rochester in 1952, both degrees in nuclear physics. He subsequently has been awarded ten honorary degrees from universities in Canada, France, Germany, Italy, South Africa, and the United States.

Dr. Bromley is married to the former Patricia J. Brassor, and they have two children, David John and Karen Lynn.

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. TRAXLER. Thank you very much for your statement. You certainly are attempting to bring to the agency, as well as to our government, a coherent, rational approach to science matters. We applaud you for that and wish you well in your endeavors. You certainly have the support of this committee in that effort.

I would like to introduce Mrs. Boggs on my right from New Orleans; Mr. Stokes on my right; and I believe you are well acquainted with the distinguished gentleman from New York City, most valuable member of this committee, of course. Mr. Green.

Mr. GREEN. I think you understand from your statement that we use this annual appearance of the Science Advisor to the President not just to review the budget for the office, important though that is, but also to discuss larger issues of science policy that come before our subcommittee, and in the full appropriations committee as we consider NASA, NSF, EPA and other agency budgets that have scientific value.

Let me start with your office. You have covered some of this, but various Presidents have obviously looked to the Science Advisor for rather different roles and have different views of the office. I understand from Bill Golden, who is a good friend and who advised President Truman, that when he first set it up it was primarily oriented towards the advice on science and technology matters relating to the military.

Mr. BROMLEY. That is correct.

Mr. GREEN. President Nixon didn't think much of the office and tried to abolish it. More recently, I have had the impression under the Reagan administration that the office was used primarily to argue the administration's case on science issues to the science community, in contrast perhaps to its earlier function of moving opinion from the science community to the President. And I wonder how you see it functioning as among those various options?

Mr. BROMLEY. Well, to put it briefly, Mr. Green, I would say that I really have two functions.

First of all, is to provide science and technology for policy, and second to provide effective policy for science and technology. In the first, my responsibility is to provide to the President, and where appropriate to the Congress, the best possible science and technology input to high-level decisions that I can get. I think that something that hasn't been emphasized in the past, in that connection, is that I also have the responsibility to make sure that not only do I bring forward the science and technology, but also I have to give the recipient some feeling for how reliable the particular science and technology is, how well we really know what we are presenting.

Unfortunately, as we all know, decisions have been made in the past on pretty hairy science and technology. Quality control is an important part of it.

Within the—the other side of the house, the policy for science and technology, obviously I have to be involved in helping you and the President make those incredibly difficult decisions between the support of the individual researcher, the small group researchers, who I still think of as the backbone of American science and technology, and the investments in the major facilities that these same people are going to require a decade or so in the future, if they are going to stay at their frontiers. It spans that whole range of activity.

In my case I think I am very fortunate as compared to my predecessors, because the President is very much interested, is very supportive, and the fact that I have access to the Cabinet Councils means that I can get this input in and be aware of developments that can and will impact science and technology before they get beyond the discussion stage.

COOPERATION WITH THE CONGRESS

Mr. **Green**. You mentioned wanting to be of more help to the Congress than perhaps other advisors had been in the past.

Mr. **Bromley**. Yes.

Mr. **Green**. Obviously we have a lot of places we can go. Congressional Research Service, Library of Congress, General Accounting Office, we have committee staff within our own congressional boundaries. Going outside, we read with interest the National Research Council publications and those from other scientific bodies. How would you see yourself relating to all those sources in terms of myself as a Member of Congress?

Mr. **Bromley**. In particular, Mr. Green, I recognize first of all the tremendous resources you do have, and one of my first acts here in the city was to meet with the staffs of the Library of Congress and the Congressional Research Service, and that whole group, because we really have a common responsibility to help both you and the administration.

But I think that the area where I would most be interested in cooperating and working closely with you is as we start this cross-cutting, integrating activity in various major areas relating to science and technology across the whole spectrum of the Federal Government. We want to be sure that what we are headed for in terms of a national program is something that you and your colleagues are going to be happy with. There is really no point in our putting together some great structure and then bringing it to you only at the end.

I would like to be able to work with you and your staff as we put these programs together, to be sure that we are all heading in the right direction.

THE QUESTION OF MEGA PROJECTS—THE SUPERCONDUCTING SUPER COLLIDER

Mr. **Green**. You alluded to problems of big science versus small science, and I know our Chairman has some questions on the space station, which also very much reflect my thinking, so I will leave that for him to initiate, but let me just say at this point—that he and I have written almost identical questions. But let me turn to another big science issue, which is not really our subcommittee's jurisdiction, but may illustrate the problem, the superconducting supercollider.

Mr. **Bromley**. Yes.

Mr. GREEN. Which involves a very substantial, I gather—and the estimates are going up, which is not unusual—expenditure. I am not a physicist, so I will just say my understanding is purely a layman's understanding of what we would hope to get by way of scientific information.

But I thought that one of its purposes was to deal with the possibility that there might be more than three masses, and that issue now has, to some degree, been laid to rest, which seems to establish a high degree of probability that there are only three, as I understand. Doesn't that raise a question whether we need at this stage the higher energy levels that the superconducting supercollider would give us, does the project make sense in view of what they have told us?

Mr. BROMLEY. That is a good question, Mr. Green. I think the answer is, however, that that is only a part of the really enormous vista of questions that the superconductor supercollider will give us access to that we already know about. There are a great many more—and the most important ones I am sure that we don't even conceive of—but let me mention a few.

The one you mentioned, of course, where you can put a limit on the number of fundamental families in nature is of course very important. But there are two very important questions that I think are much more fundamental even than that. The first is the question of where does mass come from? We frankly don't know where mass comes from. We have two quite distinct possibilities.

On the one hand, we have the theory that says that lurking out there somewhere is something called the Higgs Boson. And the Higgs field couples to all the rest of the universe and gives all the particles the mass that we observe, the measurable mass. Unfortunately, although we have looked for a long time, we have never found the Higgs Boson.

And so other theorists, not to be stymied by the fact that the Higgs might not exist, have come up with a totally different theory, the supersymmetric theory, which has given people a lot of yuks in the media, because in super symmetry, every particle has a partner, none of which we have ever found. While we have W particles in the real world we would require what are called Winos in the other world, and people have had a lot of fun with this sort of thing. But we have these two theories of mass origins.

That is one of the very fundamental questions, because it underlies everything that we ask about the structure of our universe. The reason for going to the 20 TEV, SSC is specifically because we are quite confident that that is high enough to really nail down the Higgs, if it exists.

The second question concerns what you have undoubtedly heard of the Standard Model, which is a marvelous mathematical construct that ties together just about everything we know about nature. However, we already know that it has a fatal flaw, because if we calculate the probability that one of the W's will interact with another W, as the energy increases—when we get just above about 1 TEV of energy—the probability that they will interact becomes greater than 100 percent. Of course that is just a way of a mathematical model telling you that you don't know what the hell you are doing—when probabilities start coming out bigger than 100 percent.

We have learned the hard way that if we are going to answer questions in the energy range from 1 to 5 TEV, then we really need energy about an order of magnitude larger, or we won't get enough cross-section to really do the experiments. Retesting and finding out what is wrong with the Standard Model that explains everything else is crucially important; so also is finding out where mass comes from, why do we have mass? These are two major questions that are still totally unresolved.

But as I said at the beginning, sir, the most important questions and the most exciting ones I would wager with large odds haven't even been thought of as yet.

Mr. GREEN. Let me defer to our Chairman. I do have some other questions.

COST ESTIMATES

Mr. TRAXLER. Mr. Stokes is running behind schedule and he is going to have to leave, but before we get to his questions, I just want you to know that we too are trying to configure the universe, but from an appropriations standpoint. Our problem is that we are advised these mega-science projects will cost *X* dollars, and then we get into an equation where in the course of the construction, the equation ends up at 3*X*.

I could run through every mega-science project and tell you the figures that were given in order to allay our fears of the overall cost, I suspect, are always doubled and tripled and sometimes quadrupled before the project is completed. And the superconducting supercollider is a classic illustration. It is like the Washington subway.

Mr. BROMLEY. With respect to history, sir, I won't argue with you for one moment. But I do believe that this SSC project is going to be under totally different management.

If I may say so, sir, as a physicist, we have had a rather unholy arrogance in the past. We were the ones who designed, built, operated and used all these big facilities, and the big problem in nearly every one of those—and you are absolutely correct in your analysis—was that during the course of construction, we were down there twiddling things and saying, "hey, I know how to do this better," or, "I can fix this to make it a little more powerful," and so on, leading to a flood of change orders.

They are like those you give your architect. You can throw away three bedrooms and get no cost benefit at all, but if you add a clothes closet, it costs you your left leg. The same principle works in the accelerator business.

In SSC I think we have all recognized—and most assuredly Admiral Watkins has recognized—just the worry that you have; and this project isn't going to be run by physicists. This one will have to be run—and in fact as you know, DOE just announced the main project contractor, and the major function of that contractor will be telling physicists like me that no way, once we get a final design, can we fool with it and we can't change it and we can't modify it; and the contractor will be determined to bring it in on budget.

Quite frankly, sir, if we don't do that, we are in terrible trouble from our side as scientists, because we recognize that it will put you in an impossible position.

Mr. **Traxler**. I might add that I think there is a certain amount—and I am not referring to yourself or even to this administration, but I think around this town, there is a certain amount of gamesmanship that goes on in terms of the mega-science projects. They are intentionally sold to us with a low price tag, with the understanding that as the project begins to gain momentum, it gains friends within the Congress, and outside in industry, and that those kinds of supporters will be able to roll the high numbers, while the rest of us are asking questions.

The point of the matter, I think for the integrity of the process, and for future big science projects, is that game players have to understand that those techniques are no longer acceptable. We have got some big science projects that are coming on, and we will expect a high degree of forthrightness and candor in terms of the cost, and more importantly, accuracy.

Mr. **Bromley**. Sir, you have every right to expect this in my view. I would however point out, if I might, that when the first cost estimate came in to you for the SSC, after Mr. Reagan had given it his approval, we all knew—although we didn't make much of it at the time—that the cost estimate had been based on a conceptual design study.

The one thing we all know—I have been in experimental physics for forty years—the one thing we all know is that when you turn the job over from the conceptual design folk (and I know you were told that you had gotten the best numbers since the estimates on the ARC, but what you actually were getting was the conceptual design estimate) to the real professionals, the people who are being told, "Fellows, you are going to have to build this thing; it is your reputation that is on the line; you are going to make it work the way somebody said it was going to work," they are always just a little bit more conservative than the conceptual design group.

The fact that you have seen the magnet bore go up from four to five centimeters, and the injection energy from 1 to 2 TEV, is I think a reflection of that conservation.

But Admiral Watkins has assured me, because I have asked him just the same question that you have, I am committed, because now with two Presidents and you in the Congress having said that this is what you want to do makes it a very high priority, so my job is to make sure that it comes through and does what it is supposed to do within the kind of funding that makes some sense.

I have been asking the Secretary, "When are you going to be able to tell us really a good number on what this is going to cost." And he recognizes the importance of this, and that is why we don't have a good number at this point, because he is scrubbing, with a huge staff, the numbers that he has obtained from the professional group that are going to build this machine, and I suspect that when he comes forward to give you those numbers, that they will be numbers to which you should give substantially greater trust than many of those you have had in the past.

Mr. **Traxler**. Thank you.

Mr. Stokes?

THE FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY

Mr. STOKES. Thank you, Mr. Chairman.

Mr. Director, I notice that you have set up a new Science, Mathematics and Engineering Committee that will have an interagency type of coordinating function, and I note further that you have indicated you are trying to get DOE to be a part of this and have their cooperation.

Mr. BROMLEY. Yes, sir.

Mr. STOKES. How successful have you been in getting their cooperation?

Mr. BROMLEY. I thank you for that question, sir—because I have been extraordinarily pleased at the cooperation I have gotten from all the agencies, and from all the members of the Cabinet. We have had a full meeting where they attended; we are going to have another one March the 1st; and I am very optimistic that we will have the support from them, both in principle and in terms of providing an Executive Secretariat to operate FCCSET, as well as their personal participation, which is vastly more important, if I am to make this really work.

I am very pleased with the cooperation that we have obtained from everyone. We found to our amazement when we first looked at FCCSET, that for reasons that are lost in the mist of history, the Department of Education clearly had never been a member and so, we are going through the appropriate motions to ask your permission to have the Department of Education join us. Just about everything we do has an education component these days, and we want to be sure that they are represented. Secretary Cavazos and his staff are very enthusiastic about that.

EDUCATION IN THE UNITED STATES

Mr. STOKES. I am glad to hear that. Let me take it just a little bit further.

I have some very grave concerns, as I know other members of this committee do, about the whole educational picture in our country at this time.

Mr. BROMLEY. Yes, sir.

Mr. STOKES. Secretary Cavazos recently described our math and reading skills of American children as being abysmal, and yesterday, for instance, we had testimony from NSF, and they said that six—only six to seven percent of graduating seniors graduate with a level of science where they can enter college-level courses in science.

Then the problem, it seems to me, is compounded when we look at the situation relating to woman and minorities.

Mr. BROMLEY. Yes, sir.

Mr. STOKES. So we have not concentrated on, in terms of preparing them for the enormous burden that they are going to find on themselves 10 years hence in the new work force, the year 2000 and beyond.

What emphasis is your agency putting on this situation?

Mr. **Bromley**. We give the question of mathematics and science education, that has three components that I will come back to in a moment, the highest priority, in our entire Office. This follows because we believe that unless we can develop on the one hand greater literacy among our broad public, and at the same time an adequate number of professionals, and moreover, the "forgotten middle" in this country, which is terribly important, (those are the technicians, super-technicians) unless we can make progress in all three of these areas, we simply are not going to continue to compete in the international marketplace in which we find ourselves.

I have been a teacher for some 40 years, and I have characterized publicly—and I am happy to do it here—that at the pre-college level, we are perpetrating a fraud on a very large fraction of our children—no question about that.

At the college level, because we are the only country among the developed nations that doesn't have some kind of centralized control over what constitutes a college education, we have peaks of excellence that set world standards, but we also have troughs of mediocrity that really defy description.

On the average, we are competitive, though, with the rest of the world. At the graduate level, without question, we set the standards for the world, and graduate education is probably one of our most important exports.

And you may ask, how can we be so good at the graduate level and yet so bad at the pre-college level; the answer is simple, and it is scandalous. It is just what you say. We are prepared to sacrifice an enormous fraction of our young people along the way, and in math, science and engineering, a disproportionate fraction of those who are dropped along the way are minorities and women.

This country simply can't afford that any more. We are working very actively now with other branches of the White House to follow up on the President's Education Summit, to follow up on his meeting with the Governors.

We in OSTP are being given responsibility in the mathematics, science, and engineering area, and the committee that I am putting together under FCCSET—Human Resources and Training—will first of all pull together all the activities that are under way under the aegis of the agencies and then take the best examples we can find there and begin to catalyze their spread.

We want to use the national laboratories, and Secretary Watkins has already provided real leadership there—use the national laboratories to really act as focal sites for improved education in their areas.

We want to convince industry that they have to get involved much more than they have in the past. We are putting together a private sector panel on just that point, under PCAST, and one of the most important things probably of all is the work that we are doing to help in developing national goals—not national curricula, because that has an element of coercion and education really should remain a local and regional responsibility.

But we in the Federal Government can develop national goals, national standards, and ways to measure performance against those standards, so that each year, each child, each school, each

State and the Federal Government can get a report card on how well each is doing.

The goals that the President has announced are enormously ambitious ones, but I believe that by working together, we can meet them.

Mr. STOKES. Mr. Chairman, I have a number of other questions I will just submit for the record, since I have to make this other meeting, and I appreciate very much your indulgence.

Mr. TRAXLER. We understand.

Mrs. Boggs?

Mrs. BOGGS. Thank you, Mr. Chairman.

It is so nice to have you with us.

Mr. BROMLEY. I am delighted to be here.

WOMEN AND MINORITIES IN SCIENCE

Mrs. BOGGS. I have to tell you that I sit on the other subcommittee in Appropriations that has responsibility for the supercollider, and I greatly admire Admiral Watkins, especially for his expert knowledge of and his long experience with nuclear reactor safety. He has been charged with particular responsibility for addressing nuclear and hazardous waste, and I want to be as cooperative with him as I possibly can.

I am also pleased that he is assisted by my colleague, former Congressman Hensen Moore from my home State of Louisiana. With the culmination of their legal and scientific knowledge, and with their expert ability in staffing projects, their efforts will be very successful.

I would like to follow up a little bit on Mr. Stokes' comments. Mr. Stokes and I and this whole committee have been very committed to ensuring that women and minorities have been appropriately represented among government programs, including educational programs.

Of course, as you are aware, the Task Force on Women, Minorities and the Handicapped in Science and Technology recently released their final report, highlighting the strong need to recruit more women and minorities into the scientific and technological careers.

As OSTP has recognized, and I quote

> No longer an equity issue only, the role of women, minorities and the handicapped in science and engineering is an economic issue of great importance to the Nation. The participation of these traditionally underrepresented groups in science and engineering is essential for building the technological work force required for the Nation's economy.

The task force's final report points out that despite an array of efforts over the past decade by government agencies, private foundations, States and the industrial sector, substantial underrepresentation of these groups continues to exist.

In fact, the report states there is little reason to assume this enormous underutilization will be reversed in the future without substantive changes in our approach to the problem.

What action will OSTP take to encourage the participation of more women, minorities and handicapped individuals in the technological work force, and to reverse these disturbing trends?

Mr. **Bromley**. Well, I stand by the statement you quoted; I believe it is a very serious question, and the difficulty with both women and minority participants in science and mathematics and engineering, I would submit, is one that begins much earlier in the educational system than we have tended to address in the past.

We have tended to focus on high school, college, and perhaps beyond. The real problem, it seems to me, is way back in preschool, elementary school, and certainly in junior high school. We have to realize that in mathematics, engineering and science, career decisions, as distinct from most other professions, are made prior to the junior year in high school, in almost every case.

If you have lost the interest of the students, if you have convinced the students that they are not interested in a career by that time, you have lost them permanently. The first order of business, as I see it, is that we have to go back to the elementary and high schools and we have got to provide the kind of education in mathematics and science that, first of all, is attractive and that doesn't scare people.

I am appalled at the number of times I hear, even today, of teachers in high schools telling women that they shouldn't have anything to do with anything mathematical, because women just don't do well in mathematical subjects. That is complete nonsense.

Minorities, too, are urged, in a great many schools, not to get involved in mathematics or the sciences, and so we don't attract anywhere near the fraction of women and minorities back at the elementary and security schools to take courses that might prepare them for, or interest them in science or mathematics as compared to any of the other developed countries.

And secondly, the quality of the teaching tends to be so low, that even for those intrepid souls who decide that "despite what you tell me, I am still going to hang in there and I am going to be a mathematician or a scientist or engineer," they have such bad preparation that I recently was told by a large group of university presidents in this country that what used to be four-year programs at the undergraduate level are now really two and a half-year programs, because one and a half years are devoted strictly to remediation.

It is distressing that the statement has been made that, instead of the three Rs, we now have the six Rs: Remedial reading, remedial writing and remedial rithmetic. It is sad, but unhappily it is also true.

You will note that the Governors that have been meeting with the President in the last few days have made one of their recommendations that they would increase the mathematics and science certifiability of teachers by 50 percent, and that is long overdue, because the current statistics show that 45 percent of the people teaching mathematics and science in our high schools today have no formal training in either.

We really don't have to look much beyond that to recognize just how unfair we are to our children. For the first time in the history of this Nation, our children are getting a poorer education than their parents did, and that is a sad commentary.

Mr. **Traxler**. Can I ask a question?

Mrs. **Boggs**. Certainly, Mr. Chairman.

Mr. **TRAXLER**. Dr. Bromley, there is a tendency, I think, on the part of our Nation to place a tremendous responsibility upon the educators.

Mr. **BROMLEY**. I agree.

Mr. **TRAXLER**. And we say, if there is something wrong with education, it must be the teachers or the educators. No one looks at our culture or family structure.

Mr. **BROMLEY**. Absolutely right.

Mr. **TRAXLER**. Let me just give you one statistic. I think it explains to a large extent the problems that we are having in education. The average high school student spends twice as much time in front of the television set as in front of a school teacher.

Mr. **BROMLEY**. That is the sort of thing that cuts to the quick, isn't it?

Mr. **TRAXLER**. We don't have to say any more.

Mr. **BROMLEY**. That is right.

Mrs. **BOGGS**. Perhaps we have to make one of those marvelous matches between teaching and television.

Mr. **BROMLEY**. Well, if I may, Mrs. Boggs, I have had the great privilege in the recent past of visiting a number of the really remarkable initiatives that have been started by the States; recently, I visited the North Carolina School of Science and Mathematics. That is an absolutely marvelous demonstration of what can be done in a State that had the lowest SAT scores in the Nation.

They have taken over an old hospital, they have brought in 500 really talented youngsters, and they have turned them loose, and it was just the most fascinating hour and a half I spent with them, because these kids, as juniors and seniors in high school, are doing what juniors and seniors in most colleges are doing, and having a hell of a lot of fun while they are doing it. They are really hooked on science and mathematics.

If we can spread the good things that have been invented in State after State much more broadly, that is a function that we should try to play here in the Federal Government.

There is another function, too, and that is that some children, particularly in minority groups, are not prepared for education when their chronological age brings them into a school. They are not prepared either mentally or physically, and that is why the President is so strongly convinced that we should expand programs like Head Start.

Mrs. **BOGGS**. I was glad the Governor stood up for Head Start.

Mr. **BROMLEY**. Yes. Some of our children are sort of behind the eight ball from the moment they approach the school, and then all the way through. We can't afford that.

Mrs. **BOGGS**. Early education, and involvement of families in widening children's horizons is so very important. In talking about the States, Mrs. Bill Clinton, who is an educator in Arkansas, has expanded the Home Instruction Program for Preschool Youngsters (HIPPY) that was started in Israel. This is almost a sneaky adult literacy program, because teachers are trained to go into the home to teach the parents how to teach the little children. At the same time, they introduce the parents to an array of public programs to which they are entitled and of which they should take advantage.

So, we have been very happy in this subcommittee to see the National Science Foundation programs go from graduate fellowships to ensuring that appropriate curriculum is available for the elementary levels, and even for kindergarten children.

Incidentally, Lynne Cheney at the National Endowment for the Humanities had an interesting experiment in which a suggested curriculum was devised for colleges. I was talking to one of the young people in her office, and they had literally hundreds of requests that they didn't expect.

So, there is a real need to have some sort of a national standard to which people can prepare, according to their own desires and needs. I am very happy to have you so interested in this.

An issue closely related to the underrepresentation of minorities, and one that we discussed last year, of course, is regional inequities in research and development funding.

Mr. BROMLEY. Yes.

DISTRIBUTION OF FEDERAL SUPPORT FOR EDUCATION

Mrs. BOGGS. Many of the poor States have a high minority population, and they also tend to receive fewer Federal R&D dollars. So, it would seem that by ensuring that more Federal R&D funds go to these States and their institutions, you would accomplish the dual task of improving the quality of research performed within the State, and reaching more minority students there.

What do you think of that?

Mr. BROMLEY. I would address it slightly differently, Mrs. Boggs. First of all, I think it is important for us all to keep in mind statistics that are frequently forgotten, and that is that 75 percent of all American young people go to college within 50 miles of the place they were born. That means that we have a real responsibility to provide high quality educational facilities on a national basis.

But we have been living in the presence of what I would characterize as a myth since World War II, and that the myth is that the Federal Government does not support higher education, rather it buys research from our universities.

Of course, part of that research activity has trained generations of graduate students and has supported higher education. But the tie is a peculiar one. The argument that is usually made is that we really want to spread the research funding, so that it will improve education, so that it will lead to economic development, and so on.

Unfortunately, I believe that that has not been demonstrated very effectively, and that the research support mechanism that was invented for the United States by Dr. Emmanuel Piori and Captain Robert Conrad at ONR right after the War, is the one that has given us the strongest science and technology enterprise the world has ever seen. It was based on a very simple concept. You find excellence wherever it is, and you support it.

Now, I submit that if you distribute research funding on some basis other than excellence, we will lose a lot. But at the same time, I fully support the point you are making. I think that our challenge has to be developing excellence so that the people in a much broader assembly of institutions can compete, and can compete on their own terms with the best we have.

The EPSCOR program out of NSF is a start in this direction. I personally would like to see that program expanded, and one of the things I am interested in talking about in this Human Resources Committee under FCCSET, is the possibility of involving other agencies.

Mrs. BOGGS. I was just going to ask you that question. That is wonderful.

Mr. TRAXLER. I want to inject here a thought that I have. There are many States that over the years have made extraordinary financial commitments to higher education in their States.

There are many States who have not done the same thing. There are many complaints that the distribution of Federal funds for research, which are put out on the basis of highly competitive criteria, that those funds are distributed unfairly.

I would suggest that the States who are making these complaints dedicate some of their own financial resources to lifting themselves up by the bootstraps rather than run to Washington as a solution for their home problem.

Mr. BROMLEY. That is one of the things that I think——

Mr. TRAXLER. The thing that occurs here is those States which have made substantial commitments to their higher education, and are paying that price financially through their taxes, are then expected to be taxed again to raise the standards in other universities in other parts of the country where they refuse to do it for themselves. That is not fair.

Mr. BROMLEY. Your point is very well taken, and that is one of the reasons that I like the EPSCOR program, because it does require that the States or other non-Federal sources put up at least 50 percent, and it turns out that the accounting shows that it is much more than that, that the leverage is about three to one from the States—mostly the States.

That is why I like the program, because you couldn't be more right, that what we are talking about here are States investing in their own future, and then being helped by the Federal Government once they get to a stage where they can compete with the best anywhere.

Mr. TRAXLER. There was a program that brought the other colleges and universities to the point where they "disproportionately received" what was the Federal program, to "disproportionately receive" from this research fund? How did they get there? What Federal program put them there?

Mr. BROMLEY. It started, I believe, sir, back in 1962 with a report——

Mr. TRAXLER. It started 100-plus years ago, 300 in the case of some of those schools.

Mr. BROMLEY. Well, the land grant college program was a start. The most recent injection of major funding that started in 1962 with the Gilleland Report from PSAC, which said that our space and military needs in the next decade would be such that unless this funding was increased, the Nation simply would be unable to respond, and in a time with some hysteria, I must say, after Sputnik, universities grew at 20 percent per year for a few years. They should have known better than to assume that that was a stable situation.

But many boxed themselves in by building buildings which subsequently had to be maintained, and by giving faculty tenure whom they couldn't get rid of thereafter.

Mrs. **Boggs**. The point that the Director is making about the EPSCOR States is very, very valid. The proportion of the State involvement is higher than it is in other States.

Mr. **Traxler**. I think we ought to expand the program nationwide.

Mrs. **Boggs**. I appreciate his complete knowledge and dedication to the program.

Mr. **Traxler**. Well, let me say there was an interesting dent made in the peer review process, and you may want to enlarge upon it, and I have some serious doubts about that. So, give it some thought.

Mr. **Bromley**. I understand the point you are making, sir. I have become convinced that here the peer reviewing has simply been shifted from the Federal sector back to the State one, and that they really do get rather heavily peer reviewed. I am as sensitive, I hope, as you are to the absolute need for us not to let our peer review system come unstuck.

Mr. **Traxler**. Mr. Atkins?

Mr. **Atkins**. Thank you, Mr. Chairman.

Mr. **Traxler**. I appreciate your dedication and we will see how it holds up. You know, you are looking at an immense sum of money, and for the States and for those universities and for those Members of Congress, if that sum of money isn't peer review money, it is pork. We have had to contend with that over the years in the subcommittee, this subcommittee has never, I am very proud to say this, interfered in the peer review process at the National Science Foundation; no intervention for any individual projects, and the process has worked.

It happens to be an area which I think is a credit to our government and has produced remarkable results. And I just want to caution you that the road that you are embarking upon, in my judgment, is a violation of that, and is going to lead us to earmarking of more and more money for narrower and narrower projects, for "worthwhile endeavors".

Mr. **Bromley**. I understand that there are elephant pits out there, sir, and I hope that we can avoid some of them.

Mr. **Traxler**. I am sorry, Mr. Atkins.

INDUSTRY-ACADEMIC INTERACTIONS

Mr. **Atkins**. Thank you, Mr. Chairman. I thank you for your comments, Mr. Chairman, about the peer review process, and I think you are quite correct.

One of the things that I have noticed about the peer review process in Massachusetts, where I am from, is that we have been one of the most blessed parts of the country by peer review, but the part of the State that I represent has actually suffered.

A number of colleges and universities that are certainly in the shadow of Harvard and MIT receive virtually nothing out of the peer review process. What occurs to me is that, within the peer review process, there is merit and there is merit. Inevitably, when you have human beings interacting, people tend to support people whose work they are familiar with and who they have dealt with on other peer review panels in the past. The right hand tends to wash the left, no matter what discipline you try to put into it.

It would seem that one way in which we could take some of the pressure off to turn peer review into pork is to provide some requirements where people who get grants enter into partnerships. This follows up the chairman's thoughts as well, in that the places in which the States have put their money to build excellence should be rewarded for that.

And it seems that when you take, say, Harvard and MIT, they don't have the skills in the areas that we increasingly look at as we focus on industrial competitiveness, in the actual application of certain things into the economy. And to some extent, it is beneath them to think of something that actually might be applied in the real world and might actually produce an American product that could sell better than a Japanese product, and to create some mechanisms where people who are recipients of peer review grants as part of that grant process are encouraged to find partners, particularly in the application side of things.

Is that something that you have looked at and an issue that you think has any particular merit?

Mr. BROMLEY. I haven't had an opportunity to look at that in any detail. It is a system that is being tried now in a massive experiment in Canada, and I am rather familiar with what has been going on there. It is too early yet to give a report card on that activity, but it seems to me that the idea has real potential, but it couldn't, I think, be applied across the board.

Because, you know, there are a lot of——

TECHNOLOGY POLICY

Mr. ATKINS. I am not suggesting that we apply it across the board.

Mr. BROMLEY. Of course, one of the strengths of the U.S. system is that the support coming from the Federal Government, as distinct from that in other developed nations, doesn't all flow through a common spigot, and because we have different agencies supporting activities as part of their mission needs—as part of their mission responsibilities—I could well imagine that we could develop the kind of program you are talking about in some agencies, while in others, it might not be appropriate.

But the idea is certainly one that is important. Because we have to do better in moving from the basic discovery to the attractive product, or attractive service then we are doing now, or we simply are not going to remain economically competitive, nor are we going to be secure.

We have a very simple situation. We have got to do better. And frankly, I think we can. I think it is something of a scandal, of course, that a few years ago at least, less than 4 percent of MIT graduating engineering class had the slightest interest in manufacturing or production, or anything of that sort.

Manufacturing is important. Again, we have had a myth that we moved elegantly from an agricultural economy to a manufacturing economy to a service economy, forgetting that you don't have a service economy that isn't supported by a strong manufacturing one, and your manufacturing doesn't work worth a damn if your people don't eat.

There is this sort of mythology that grows up that hurts us deeply. I believe that we have a real role here in my Office, and that is one of the reasons why I have a new Associate Director for Industrial Technology. But the Federal Government, my Administration does not like industrial policy; we don't think that we can pick winners and losers as well as the private sector can.

However, if we are going to compete in the high-technology world, we can't force our companies to reinvent the wheel independently as we move from the initial discovery to that enabling technology that is going to help a lot of industries, a lot of our national security concerns.

I think it is important for us to be in there in the Federal Government, catalyzing cooperation, getting people together, so that, as is done in Europe and in Japan, we share the risk, we share the cost, and we reduce the time to develop the underlying technology.

Then we turn folks loose to compete, in as bloodthirsty a fashion as they choose, to compete, with each other and the rest of the world.

Mr. TRAXLER. I want to commend you for that statement. What is interesting is that for the first time, I think this committee has heard some comments, such as the ones that you have just made that indicate to people in the Administration that all is not well in hard-line America, and that we are rapidly industrializing. The point that you make, I must tell you, is clearly put to me by people who are in industry in my State.

I must tell you they also said, these are large corporation managers, they also said, when are we ever going to see a change in policy?

Mr. ATKINS. If I could just follow up on that, and I would like to echo the chairman's support and appreciation for your comments, if not on an industrial policy, at least an industrial strategy, and I would hope we could get away from that debate on industrial policy and just start doing what needs to be done, whatever you call it.

But as I look through the budget to the broad concept of a science budget that we provide, it doesn't seem to me that there are particular projects. Perhaps I am missing them. There are a few, but certainly not very many that follow up on your very eloquent statement of how we get our technology and our basic research into the marketplace in a way that the private sector both shares the costs, shares the risks and also shares the benefits.

Is there something in there that I am missing?

Mr. BROMLEY. Well, yes and no. Let me say, first of all, that the single largest block of that kind of support is $100 million that we provide each year to SEMATECH, which you recognize as the, both vertically and horizontally, integrated collaboration that is trying to keep us at the frontiers of the technologies involved in manufacturing semiconductors, and that, of course, is an excellent example of what I mean by a generic or enabling technology.

In the Department of Commerce, there is a new initiative this year in what I used to think of as NBS, and still do, but is now NIST. It is a small program, $10 million for Advanced Technology Programs.

I have already been talking to Secretary Mosbacher and Deputy Secretary Murrin, and it looks—I can't obviously commit them to anything—but they seem to be sympathetic to the concept that we really should do some reprogramming to get some additional funding into this kind of program.

I am very interested in that, because I think it is critically important for us to use the institutions that we have that have already demonstrated a real ability to interact with industry, and to get technology across. NIST is one of those institutions, and so I look to doing what I can to strengthen their activities.

TECHNOLOGY TRANSFER

And of course, we are trying very hard within the Federal Departments—there are 726 national laboratories in this country. It is a somewhat amazing number. Some big, some small. What we are trying to do is to develop a sensitivity in the agencies that own those laboratories, DOE, DOD, Interior, Agriculture, all of the major Departments, that these are a national treasure, really, in terms of the people they have involved, and the technology and the know-how that is in there and that all have a broader role to play.

But the transfer out of those laboratories has been, to put it bluntly, minimal, except in some very isolated cases, and I think that the time has come when we have to get a better return on our investment in a lot of that work. That means getting it out, and frankly, big companies know how to get it out.

The people we have to help are the small companies who get put off after they get on about the third referral inside the lab when they call in asking for some help. What we need, in my opinion—and I have been pushing this since I came here—is an office in each of these labs beyond some small critical size threshold that has no other responsibility but to provide an interface between a caller coming in with a request for help, and somebody in the organization that can provide that help.

And that kind of an office has to report to the Director, I think. It has to have the Director's firm support and public statement that it is important, because otherwise, the transfer wouldn't happen.

FEDERAL LABORATORY ROLES IN EDUCATION

Mr. TRAXLER. I think that is an interesting point. There is another component here that was raised yesterday, and it may have been Mrs. Boggs who put the question to Eric Bloch, and that was, how can the government laboratories, as industry is now beginning to do, relate to the elementary and secondary school system. Do you see an opportunity here for a national policy, not just an NSF policy relative to the contracts, or the establishment of particular centers at the various colleges and universities, but do you see an opportunity here for a national policy in that regard?

Mr. **Bromley**. Yes, very much, Mr. Chairman. I think that we have a tremendous opportunity here, and we have part of the program already in place. The Department of Energy, under Jim Watkins' leadership—and well before Jim took office, in fact—has had some really remarkable programs under way.

The Argonne National Laboratories are, in a very real sense, taking over the Chicago School System and trying to rebuild it more or less from scratch. What they do is to bring teachers in on a regular basis and in summers for month-long periods, and every Saturday they bring students in at all levels, from elementary through high school, and these students actually come in and interact with real honest-to-goodness scientists, engineers, and they get revved up.

I went out to see this operation a few times. These kids get so excited, that there is no holding them back. And that is one of the ways that we are really going to have an impact on a lot of this future that we look toward.

What we want to do this year, is led by Roger Porter in the White House who is specifically working on a program to select about a dozen of the best laboratories in the country that have such programs in place, and then we want to bring senior people from the other laboratories and have them spend the summer learning how to mount such programs, and then ship them back home to establish their own kind of program.

It is the sort of activity that again allows us to use this really remarkable national resource that is represented in these laboratories in new ways.

Mr. **Traxler**. At the appropriate time, would there be an opportunity for the President to inject himself into this.

Mr. **Bromley**. You are a little ahead of us.

Mr. **Traxler**. At the appropriate time, now.

Mr. **Bromley**. We are certainly heading in that direction, and it is interesting to note that only about two years ago, when national laboratories tried to do something of this sort, someone from Washington would come down and slap their wrists and say, "look, this is not part of your charter or mandate. Knock it the hell off." I know of that happening in two particular cases.

So, we are making progress, and what we need is to make it not only possible, but tremendously desirable and approved from the highest level, the President's level, to do this sort of thing.

Mr. **Traxler**. We will welcome that initiative.

Mrs. **Boggs**. Mr. Chairman?

You know, several of the labs have summer scholarship programs for young people. I remember being at one lab where a young girl held up a shriveled ear of corn and said, "I have decided that corn likes acid rain better than no rain at all."

Mr. **Atkins**. Mr. Chairman, if I could just follow up on that one point, because I have had some personal experience working with some of the recipients of Federal science money in the education area, and the point that you raised, that what has happened in the past is that the Federal agencies have actively discouraged and the word has gotten out, discouraged people who are recipients of Federal research dollars from initiating contacts within their communities—particularly in elementary and secondary education. I am persuaded that because of that, and because of the fear of Federal regulation, and also what I think is a general bias against undergraduate and elementary and secondary education, that there is a real barrier.

And in a few instances, you mentioned the Fermi lab, in some of the other instances where that is happening, it has been enormously successful, and I don't know why very simply we couldn't in all of the applications for funding just ask a question of what will you be doing if you get this grant to work with the local school systems?

Don't even make it a requirement, but just ask them for that information, and I think that that would send a very loud and clear signal on that. It would seem to me you are in the appropriate position to do that, to just change the grant applications to include that.

Mr. BROMLEY. One of the things, Mr. Atkins, that we really want to use this Human Resources Committee that I have spoken about earlier for, is to provide a forum where the agencies that have done a good job in this area get a chance to speak before their peers and explain what they are doing, and peer pressure is going to be very large on those agencies that haven't done anything in this area to get on with it. Working in such a committee, on interagency coordination, we can do the kind of thing you are talking about.

We can change, the grant award structures, we can change general approach, and in particular, we can get, with your help, the mandate and mission statements for many of these laboratories changed so that this educational activity and this outreach technology transfer activity really become part of the official mission of the agency.

In many cases, that is not now there.

Mr. TRAXLER. Well, I want to assure you that based on our conversation with you today, we are going to incorporate that in the committee's report this year, and we are also going to make a strenuous effort for the balance of this year for the agencies coming before us to encourage them to do exactly that.

Next year, we are going to expect a report from them in this subcommittee room as to what they have achieved in that regard, and we will begin to score them.

Mr. BROMLEY. Good.

Mr. TRAXLER. It won't be a short-term effort. It is not simply a run it up the flagpole and forget about it. It is, I think, an inexpensive way in which to get some things done that we have discussed here this morning by way of elementary and secondary schools, especially in the sciences.

Mr. BROMLEY. I think that unless we can do something of that sort, Mr. Chairman, we don't have much chance of meeting the goals that we all share.

PRIORITIES IN LARGE SCALE SCIENCE

Mr. TRAXLER. Well, let's go on. 1990 was a difficult year for this subcommittee in many respects. Our section 302(b) allocation was some $1.5 billion short in outlays. We made up about two-thirds of that with the use of every scorekeeping technique that this committee could think of.

It didn't make us very popular in certain areas in town, in the Congress or elsewhere. But we got the job done. It is quite likely that most if not all of those techniques, utilizing our creative financing, I felt like a Wall Street junk bond salesman, are not going to be available to us this year; in other words, the game is up, they are on to us, the cops have arrived.

Everything depends on our 302(b) allocation. The good news is that the President, in his budget recommendations, I think, did an outstanding job in the allocation. The fact of the matter is that because of certain shortages in other areas of the Federal budget, the prospects of us totaling those numbers when the moment of truth arrives, and the vote is taken, are not very encouraging.

So, we are therefore constrained to make inquiries of those who come before us, and ask the age-old question of priorities, in the event we are unsuccessful in achieving the kind of 302(b) allocation that will allow us to adequately fund the responsibilities that this subcommittee has.

So, priorities, and Mr. Green, I think it was last year you said, and I totally agree, unless we are given some priorities in science, then nothing has priority. That should be chiseled above the door coming into this subcommittee.

Mr. GREEN. I think it was William Gilbert who said, when everybody is somebody, then nobody is anybody.

Mr. TRAXLER. So with that in mind, we are going to ask you for some assistance in some of the large science priorities. As you well remember, we are committed now, to the space station. There are certain new initiatives that begin to show up in the President's recommendations. We have got some old initiatives that, in many people's minds, are currently underfunded.

Are we at a place where we can state the relationship between the space station and the Moon/Mars initiative? Do we do space station with that as our highest priority? Where does Moon/Mars show up on the radar screen in terms of priority?

Mr. BROMLEY. This is a question where I can't give you any clean-cut answer for the simple reason that it is something that is under active discussion at the moment within the Space Council, it is under active discussion in NASA, and I don't have sufficiently hard information that I would want to give to you. I haven't been able to get the kind of information that you have just asked, and I too am very interested in it.

Mr. TRAXLER. I am about to file a Freedom of Information request. I am very serious about that, too. I want you to know that. We are having some difficulty in getting some very basic kinds of information, financial information, cost estimates on Moon/Mars, and that is troublesome. The reason it is troublesome is because very shortly, we are going to be told the justification for appropriating, I think it is $300 million.

Mr. GREEN. Yes.

Mr. **Traxler**. As the first initiative. I mean, you sort through, there are 300 million new dollars for Moon/Mars in this budget, and of course, we are going to want to know what the final price tag is. We are not going to write a blank check. This committee has been rolled too many times in the past on these major science projects to get suckered down that road.

But that is another day's question. One of the areas that we think has been underfunded, and this subcommittee bears some responsibility for this, with our budget crunch, and that is the National Aerospace Plane effort.

Mr. **Bromley**. I am a strong supporter of NASP, sir. I feel that way for a number of reasons. I think that, first of all, most of the discussion has been beside the point. It really doesn't help anybody to get from point A to point B in two hours if it takes four hours to get the luggage, so forget that.

The real argument, of course, that I see for proceeding with NASP is that the one industry that has really been remarkably successful in maintaining a positive trade balance over the years—maintaining world leadership—is the air frame industry, and I feel that moving in a reasonable pace with the NASP program provides the kind of support that will allow us to maintain our leadership in the technology that has served us so well in this air frame industry.

There are many people out there who would like to take that leadership away from us. And so, that would be my first reason for supporting the NASP. The second reason is that it holds the promise of getting us a much lower cost per pound into orbit, and if, as I am completely convinced, we as Americans are going to succeed in moving into space and commercializing space, one of the key issues is reducing the enormous cost per pound to get there.

Those are my two reasons—the first without a doubt in my mind is the support for one of our most successful industries, the second is the hope eventually, and I believe it, of getting a lower cost per pound into orbit, and the transportation argument, as far as I am concerned, is something for the Sunday supplement and not a very important part of the argument.

Mr. **Green**. Mr. Chairman?

Mr. **Traxler**. Yes, Mr. Green.

Mr. **Green**. I guess what troubles me is that I see the NASP, and I agree with you as to the importance. On the other hand, I would have to say in terms of transportation, I hear the industry talk about a three to five times the speed of sound plane, and NASP was the next technological breakthrough.

In my home community in New York City, our Port Authority is very interested in the swing rotor technology because of the inability to expand our airports as a practical matter. And obviously, this subcommittee has significant interest in this whole area, because of NASA's role in aviation research. We have had a history where NASA did the R and the Pentagon did the D in aviation R&D, and that is what enabled our civil industry to beat out everyone else.

We are now at the point where we are being told that the Pentagon can't afford to do the D anymore, and so even though some test units have been built, the President just sent up some deferrals, refusing to buy advanced parts for the swing rotor project, and I guess that leads me to the question, and I have been asking this of the White House through other channels for over a year now and gotten no answer, of how we are going to structure this thing if the Pentagon isn't going to do the development work.

Certainly the request for aviation research for NASA doesn't have enough money to pick that up. So, you know, a national aerospace plane is nice for giving you the technology for 20 years and 30 years from now, but how are we going to get from here to there if the Pentagon is getting out of the development business?

Mr. **Bromley**. I don't have a clear answer for you, either, Mr. Green. This is not an area, beyond the NASP area, where I have had an opportunity to look into in any depth, and it is one that I will be happy to take a look at and get back to you, but I simply couldn't respond in a responsible way to you this morning.

Mr. **Green**. If you could at some future point, I would certainly appreciate it. As I say, I have raised this issue.

Mr. **Bromley**. We will try to do that.

Mr. **Green**. To no avail.

Mr. **Traxler**. In the event our 302(b) allocation is inadequate, and this subcommittee is faced with difficult choices, we are asking you to assist us in making some of those choices clearer to us, NASP is important to us, Moon/Mars is a new initiative, we will be carefully questioning the Director as to the importance of it and how it fits in, and what our obligations are going to amount to in the coming years.

But if we have to make these choices based upon a limited allocation, how would you rank starting Moon/Mars as opposed to continuing adequately funding NASP?

Mr. **Bromley**. I would, I think sir, have to answer that the budget that the President has sent up is the official Administration position on this, and it would be very difficult for me to answer your question—without some difficulty.

Mr. **Stokes**. To say the least.

Mr. **Traxler**. That is what we are paying you $3.3 million for?

Mr. **Bromley**. I had hoped you wouldn't look at it in quite that way.

Mr. **Traxler**. We understand the difficult position you are in, and we are also looking for sympathy and understanding.

Mr. **Bromley**. That you have.

Mr. **Traxler**. Thank you very much.

Mr. **Bromley**. That you have. You have probably the most difficult position in the entire process, in the view of my office.

THE MOON-MARS INITIATIVE

Mr. **Traxler**. Well, we feel better now. Where you participating in the discussions involving the 90-day NASA study and the Moon-Mars human exploration effort?

Mr. BROMLEY. I was involved in some of those. I was not able to attend all of the Space Council meetings because of conflict, but I was there for part of it.

Mr. TRAXLER. What is your personal sense of the program and its importance?

Mr. BROMLEY. I think, quite frankly, my feeling is that the 90-day effort that Admiral Truly put together was really a very crude one, and I wouldn't believe—let me put it another way. I wouldn't give very much credibility to any specific numbers that would come out of the study of that duration.

I personally have felt for a long time that Moon/Mars gives us an opportunity to really challenge our technologists. Some of the technologists, at the DOE laboratories, just to give a specific example, take a fresh look at this whole thing, because frankly it seems to me that if we just used the same technology or a stepson of the old technology, that we are not taking the maximum advantage of the skills that we have in this country, and I would like to see us actually turn loose a new group of folks to try and develop a program that would be new technology-based.

I am convinced that we can develop technologies in the next couple of years that will allow us to achieve the goals which I very much support, of getting us off the home planet, but in a somewhat more economical way.

Mr. GREEN. Let me ask you this: Do you see that as having any science purpose, because every report you get from the National Research Council would argue that robots do it better. We have had a predecessor of yours come here and accept a statement I made that we could do it for about one fifth of the cost if you don't have to have the stuff manned, and in particular, the manned kind of mission on Mars, that the Moon/Mars program applies, it is certainly strongly suggested in the National Research Council report that that is not a great deal of worth in terms of the kinds of scientific knowledge gained.

Mr. BROMLEY. Mr. Green, my feeling is very much one that we can do a very large amount of science with the unmanned systems, no question. Of course, if we are dealing in micro-gravity experiments, the last thing you want around is a man jarring the system and causing vibration. But there are, however, I think some other aspects of this program that lead me to feel strongly that what we need is a balanced program that starts off with very heavy emphasis on the robotics to really, to pave the way.

But I believe that we must keep a manned program alive, and I guess the answer I would start with may strike you as highly academic, but let me simply say that if you go back and watch what happened to the Chinese, who were once the world's greatest seafaring nation, when they decided to pull back and pull within their own borders, they rapidly disappeared from sight.

And the Portuguese in the 15th Century, after being the world's leading explorers, the people who mapped out the continents of the world, when they pulled back from the frontiers, they simply disappeared from world significance and importance.

And so I look on space as the last frontier, and I think that we would not be true to the American explorers' spirit if we didn't keep this in mind. The question, however, is a very valid one. Just how big an entourage do we want to give Lewis and Clark on the space frontier, and that is a question that in the end only you in the Congress are going to be able to answer.

I am convinced that if we work together, that we can reach our goal a lot more economically than some of our current estimates might suggest.

Mr. **Green**. I was taken with your comment on micro-gravity that you wouldn't want humans around, and our staff director suggested to me he probably doesn't want centrifuges or animals either. And yet we were sold on the space station and that was because we were going to be able to do all this marvelous research. Now if you are going to have a port for moon rockets, the shuttle is sitting out there, it seems to me that you are——

Mr. **Bromley**. There is a fundamental problem, sir, and that is that it is not at all obvious that a micro-gravity laboratory is consistent with being also, simultaneously, a transportation mode, but there is, however, a rational answer that I think Admiral Truly if he were here would give you, and that is that there is an extended period in which the space station could in fact function, as an unmanned robotically operated micro-gravity laboratory.

Mr. **Green**. We have said that.

Mr. **Traxler**. You are looking at the source now.

Mr. **Bromley**. All right. I am behind the curve.

Mr. **Traxler**. We have got a lot of other ideas not only for unmanned, but also for man-tended, and somehow or other those didn't get to liftoff.

Yes, Mrs. Boggs?

Mrs. **Boggs**. I would just like to say that for Lewis and Clark first had to invest in the Louisiana Purchase.

Mr. **Bromley**. You are absolutely right.

Mr. **Traxler**. I have some rather extensive comments along the lines of Mr. Green, and it is sort of the institutional memory of the space station, if you will bear with me we will get to the question in a moment, but we want to run through the history.

Mr. **Bromley**. All right.

Mr. **Traxler**. The space station has been supported in this committee, clearly. But let me tell you what NASA's justification and rationale was starting back in 1984 when it was first proposed.

First it was to provide the United States with a first-rate micro-gravity materials laboratory; it was to provide the United States with a first-rate life sciences laboratory; it was in addition, to provide us with a major servicing facility for a large national telescope, such as AXAF or Hubble; additionally it was conceived as a platform that would mount literally dozens of instruments to look at the stars; it was also a staging area for geotransfer orbit launches; and finally, it was noted that it could be used as a jumping-off place to establish a colony on the Moon or Mars. That was back in 1984. We have been through a lot of budget crunches and a lot of descoping on this subcommittee. We encouraged NASA early on to take an incremental approach to this mega-science project, and unfortunately our voice wasn't heard. Now what is left is a space station that we are struggling to keep as a laboratory to do first-rate U.S. micro-gravity materials research.

I might add that our allies or partners, as we say, their first area of concern, and virtually their sole area of concern is micro-gravity research, and that should send us a signal. I haven't met any stupid Japanese, and certainly no dumb Europeans, and if they are doing micro-gravity research, it is for a reason. And I would hope that as we proceed, that that will remain one of our first and foremost objectives.

But having said all of that, and remember, we are paying now some $30 billion for Station, including launch costs. Can you tell us what you believe to be, as the Science Advisor of the President, the purpose and goal and the mission of Station ought to be?

Mr. BROMLEY. Well, sir, from my own experience, I am not that well versed here, but I can tell you what I am being told, and I think probably we both share similar beliefs. I think there are three major areas.

First, I would agree completely, is the micro-gravity question. I think there is a real opportunity, and I have felt for a long time that material science is one of the orphaned areas of our whole activity in this country, and we ought to do something about it, so micro-gravity is clearly important.

Secondly, I think if we really do intend to move off the home planet, that we have a great deal to learn yet about how humans acclimatize to long duration space flight, and if we are going to do that, the place to do it is in a space station, at least close to home on an astronomical scale. That is the second area.

And the third is again this question of a transportation node broadly defined. I don't think anyone has yet settled, exactly how one would do that; it is something that is going to depend on what our technology tells us, and how the program moves forward, but there is the question of do we go space station, then something on the moon, and then to Mars, or do we go to the space station and then to Mars, or do we go the moon and then to Mars, and skip the space station?

All of those options are being looked at, and I don't have the expertise to tell you what the true experts are going to come up with.

Mr. GREEN. It troubles me that they are being looked at six years after we started the space station program, and my complaint about this all along, is that we are building a station and then looking for purposes for it, instead of deciding what our purposes are and then building whatever most economically would serve its purpose.

Mr. BROMLEY. That is why I thought it was so important that President Bush, last July 20th, attempted to articulate a long range program for us on the space frontier, because for a number of years I too shared this conviction that unless we had some kind of long range program, series of goals, milestones, that we were going to drift. And I am very sensitive to the point you have just raised in terms of our international science and technology status, because unhappily, and—and we need not have done it, frankly—we have become known in many quarters abroad as "unreliable partners," and we have—that has occurred because we attempted to make changes in some of the areas like the space station without due consultation and discussion with our partners.

Mr. TRAXLER. Dr. Bromley, I think that is an important point. I think that needs to be addressed and we need to discuss that for a moment, and part of that, in my judgment, comes out of the number games that again are initiated at the very beginning of mega-science projects.

Mr. BROMLEY. Yes.

Mr. TRAXLER. The efforts on the part of their supporters in the incubation period to downscope the cost of the project in order to sell it to the Congress is the same old story. Let me get my foot in the door, and then it is all over. The classic illustration: we started out with a station that was $8 billion, the 1984 estimate. It was going to do everything that I told you a few moments ago; and now we are at $30 billion and it is still going.

Now, one of the things, if we are talking about our allies and they think that we are unreliable, imagine how we feel on this side of the table about reliability of the information that we are getting from that side of the table on these projects. If you have any voice with any of these people, please tell them for heaven sakes, come clean guys, because you are destroying your credibility, and you are harming science.

Mr. BROMLEY. I get the message loud and clear, sir, and in the Space Council I have already been trying to do something of that sort.

Mr. TRAXLER. I wish you well.

I am sorry, Mr. Green.

Mr. GREEN. Nothing further.

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

Mr. TRAXLER. We want to commend you, incidentally, for your support of the International Institute of Applied Systems Analysis, IIASA. We think that is an excellent program. It has been hard going in recent years to convince others elsewhere on that point.

Mr. BROMLEY. I am glad we are finally back on board.

THE EARTH OBSERVING SYSTEM (EOS)

Mr. TRAXLER. We think that it is a participation that will be beneficial to this nation. Keep up the good work.

Let's move over to EOS for a moment. How do you see that as a priority?

Mr. BROMLEY. I give EOS a very high priority, Mr. Chairman, and the reason is simply that having spent as much time as I have in this last several months in this whole question of global change, it becomes very clear that one of the problems that we face in coming up with appropriate U.S. policies is that we lack adequate data, on the global environment, and the thing that the EOS will do that nothing before has done is to allow us to look at a given point on the earth's surface, to scan the earth simultaneously, that is the key word, simultaneously with 14 to 15 instruments.

Up to now, we have lots of data. We have more data then we know what to do with, but it has been taken one shot at a time at different times and under different conditions, and so it is almost impossible to intercompare any of these data sets, because who knows what cloud came across in between the two satellite passes and so on.

And so I think EOS is very important. I think that it gives us an opportunity to, for the first time, really get information that will be of enormous importance, not only for the usual global change type studies, but it is going to be tremendously important in terms of agriculture, in terms of aquaculture, in terms of knowing what is going on in the earth's oceans, of giving us early warning of all manner of developments in biology, and hydrology—you name it.

But I think also that it provides us with a very natural way, just from the structure of the platform—here is a platform and we need 15 world class instruments aboard and a marvelous opportunity to have international cooperation as we start right from the beginning, and go out and get the best people in whatever country they may be found to build those instruments, to fly on EOS.

I think that is critically important. And it is a way that we in the United States, who really earned our leadership position in the whole global environmental science area back in 1957 and thereafter, can really maintain that leadership in a very major way.

Mr. **Green**. Let me ask this. From your comments, you seem to be coming out in favor of one superplatform as opposed to multiple platforms.

Mr. **Bromley**. Yes. Actually, I think it is important for us to have two platforms in orbit, but I prefer the large platform for the simple reason that it allows the simultaneity, because that is of critical importance in determining what you can do with the data. Because if I look at a piece of forest with all these instruments simultaneously, I can then tell all manner of things about the biology, the health, and all sorts of things about it. I can't do this from single shot observation.

Mr. **Green**. There are two arguments on the other side. One, that some of the instruments work better at different heights from others.

Mr. **Bromley**. Yes.

Mr. **Green**. But I think perhaps of more concern to me is that we see NASA steadily slipping from the date when this thing will be up and running. Initially it was 1995, and now they are telling us 1998.

Mr. **Bromley**. That is a real concern.

Mr. **Green**. And I suppose the question is by giving this a higher priority than, say, Moon/Mars, could we get this up faster, on the superplatform basis, and then start getting the data?

Mr. **Bromley**. Well, that is an entirely appropriate question for you to address either to Admiral Truly or to the President, because that really is the kind of question that in particular the Space Council is supposed to be addressing. It is a very good question.

Mr. **Green**. Do you have a priority from a science point of view as to which you would see——

Mr. **Bromley**. As I said before, three weeks after the release of the 1991 budget, I would not wish to tinker with it at this time.

Mr. **Green**. I guess we are getting back to the point that at some point this subcommittee will have to tinker with it. And you know, if you want to—if you really want to be helpful to the Congress, letting us know what the priorities are——

Mr. **Bromley**. As I leave Washington.

Mr. **Traxler**. We appreciate the candid, direct response.

Mr. **Green**. We understand that you are the coordinator of the study of the earth orbiting system program, so that in a way, it won't be the Space Council or OMB.

Mr. **Bromley**. From my vantage point—the point that I would emphasize, Mr. Green, is one you know perfectly well too, and that is that in decisions of this kind, science may be an important component, but it is not necessarily the dominant one. And so there are other—you know, the political, the international, all of these issues that are outside my immediate purview, and that is why I would hesitate to answer.

SCIENTIFIC PRIORITIES

Mr. **Green**. I agree with you, and I understand that the Moon/Mars program could have no scientific benefit whatsoever and still be something the country might choose to do, and that would be a decision that Congress has to make, the President has to make and you don't have to make.

But you can tell us which is more important from a science point of view, and if you would like to weigh that, acknowledging that you can't give us a judgment on other national purposes on Moon/Mars, I then get back to which from a science point of view is more important, the earth orbiting systems, Mission to Planet Earth kind of activity, or Moon/Mars. It is strictly from a scientific perspective, recognizing each of them have reasons to proceed or not to proceed.

Mr. **Bromley**. The reason that it is extraordinarily difficult to answer you, Mr. Green, is that of course, from my parochial vantage point at the moment, I am very much interested in getting the best global data information to earth, I think it is extremely important, so I tend to be something of an enthusiast about that.

But on the other hand, I have talked to many of my friends who bend my ear regularly, to forget that, what we really want to do is to get on to the moon, because an astronomical base on the moon would just be the best thing since sliced bread for the astronomy community.

And each of these communities have their own very special enthusiasms.

Mr. **Green**. I thought one of the reasons we had a Science Advisor was to give us some sense among those communities what are the priorities from an overall science point of view.

Mr. **Bromley**. That in fact is a true assumption. However, the forum in which I am supposed to do that is within the Administration, and in discussions with the President and Mr. Darman, and I assure you that I have already done that. The budget you see is in some measure a reflection of that, and it would be improper of me outside of that process, to then perhaps give an answer which reflected my personal feeling, but was not the one that we had reached by consensus within the Administration.

Mr. **Green**. What you are saying to me, I don't disagree with the conclusion you reached as to what your role is, but the conclusion you are saying to me is really, when push comes to shove, this subcommittee isn't really going to get a lot of priority-type science advice from the Office of Science and Technology Policy, when it comes to budget priorities.

Mr. **Bromley**. If you were to officially ask us to do this, we would do the best job we could in giving you the measured scientific opinion. But to do it today without having a chance to go back and take a look at the alternatives, some of which I haven't studied nearly as deeply as I have the EOS, to give only one example, would be unfair.

So I have to be careful in the sense that as I said right at the outset, my function is to give you the best science and technology advice that I can, not necessarily just my own.

Mr. **Green**. It will be a couple of months before we mark up, by then you can tell us more. I would certainly appreciate it. Thank you.

Mr. **Green**. I don't mean to be pushy.

Mr. **Bromley**. I understand.

CIVILIAN AND DEFENSE R&D

Mr. **Traxler**. Recently, a science writer writing in the Baltimore Sun said as follows, and I quote: "Its choices reflect obsession with the ghost of the Cold War. Today, Asian-made VCRs and automobiles, excellently designed, and skillfully manufactured, threaten American security more than the Red Army.

"But in Mr. Bush's new budget plan for the division of precious government research funds, the Pentagon gets 16 percent of the total and the civilian agencies, 39 percent. Sensitive to these numbers, the President's Science Advisor, D. Allan Bromley, points out that civilian research used to be even worse off in the Federal budget, but that recent trends have enlarged the share of the pie.

"That's true. But the shift that has taken place in favor of civilian research is slight. A close look reveals that much of the growth is consigned to glamorous mega-projects, while only sparse sums are provided for industrial purposes. Thus, money for the manned space station is up by 36 percent to some $2.6 billion, in next years budget, though a growing weight of independent, expert opinion holds that the space station venture is an extravagant boondoggle, with little scientific or industrial merit."

What are your thoughts on that?

Mr. **Bromley**. Well, let me respond in several sentences. First of all, the comparison of the civilian and military research and development budgets is something that must be approached with some care. It is an apples versus oranges question, because 92 percent of the defense R&D is earmarked for specific weapons systems, and therefore would not fall into the same definition as the R&D in the civilian sector.

Only 8 percent of the defense R&D would really fall under the same set of definitions that the civilian does. And so that tilts the argument badly right from the very beginning.

I personally believe, Mr. Chairman, that a time of lessened tension, such as the present, is just the time when the basic defense R&D should increase, because we need to protect ourselves against technological surprise and being blind-sided.

I also believe that the Defense Department should work to regain something of the status it had in the fifties and sixties, as the favored supporter of university basic research, because that gave the Defense Department contact with some of the best minds in the country, and some of the smartest young people. Those bridges were burned during the Vietnam period.

I think it would benefit both the Defense Department and the universities to get them back together. I have talked with Secretary Cheney, Secretary Atwood at some length emphasizing this, and I was delighted to see that in a time when large areas in the Defense Department were taking a beating, the 6.1 research area was scheduled, for essentially a 6-percent increase, and the 6.2 area for a 4-percent one, both are pretty good.

Mr. TRAXLER. Perhaps in your mind.

Mr. BROMLEY. Compared to what it could have been.

Mr. TRAXLER. We talked earlier about industrialization. We see the lessening of these tensions as an opportunity to begin to rebuild this Nation's infrastructure, both the fiscal and the human.

Mr. BROMLEY. Yes.

Mr. TRAXLER. And simply putting money in the same old place in the Defense Department simply doesn't respond to the Nation's need in this decade or the coming century, which I think you said in your opening remarks, if not your first sentence. It is economic warfare.

Mr. BROMLEY. That is right.

Mr. TRAXLER. If we continue doing things the way we have and allocating our resources and priorities to the Defense Department, we deserve what is going to happen to us.

Are there any further questions?

SCIENCE EDUCATION

Mr. GREEN. This is a totally different field. Some years ago, I asked during our National Science Foundation hearings what we knew about why some of the groups did so well academically, particularly in the sciences, and I was told of a rather discouraging NSF study which showed that first-generation youngsters of Asian origin in California did brilliantly, the second generation did very well, and the third generation was slightly statistically distinguishable from the mass of students as a whole, and the fourth was part of a blur.

While that may sound reasonable to those who subscribe to the melting pot theory, I find it kind of sad, and I would like to know, is there some way we can find out what it is that that first generation has, in the case of Asians, or had in the case of earlier immigrant groups, and how we can make that attitude, if it is an attitude difference, available to others in our society who seem to find it so hard to break out of poverty and the inner city problem?

Mr. BROMLEY. I think there is no question whatever about what the difference is, but how we get it back is a totally different ball game. The crucial parameters as far as I am concerned are parental interest and parental participation in the education of their children.

If the parents think it is important, and if the parents are prepared to sit down and work with the youngsters and work with the teachers, make it clear to the kids that education is the most important thing in their life, and shut off the damn television set, things of that kind, then I think we would be in great shape.

How we go about telling today's parents that that is important, I frankly don't know. I, too, have been impressed by these surveys, comparing our performance to the Japanese performance, for example. You read them, and you find that not only are we guilty of ignorance, we are guilty of arrogant ignorance, because when asked, how are they doing in mathematics, our kids, who are scoring miserably say, "Oh, great."

And you ask a Korean youngster who is scoring in a magnificent fashion, and the Korean says, "Oh, I have much to learn." We have a serious cultural problem, it seem to me, that underlies all of the other things we have discussed, and I frankly, sir, don't know how we can get back the parental interest in the education of our children.

I sense that it is going to happen, because parents are beginning to recognize the truly terrible state of our educational system, and they recognize that what is happening to their children shouldn't happen at all.

Mr. **Stokes**. Mr. Chairman?

Mr. **Traxler**. Yes, Mr. Stokes?

Mr. **Stokes**. While I would not disagree with you in terms of the parental emphasis, and in fact, I well know that some of our school systems around the country are now combining a system of parental involvement along with teacher involvement in the schools as a new thrust towards helping children, but we have got a country in which you have approximately 24 million functionally illiterate adults.

It is very difficult for them to place the proper emphasis upon education themselves when they are functionally illiterate.

Mr. **Bromley**. Yes. I wish I had an easy answer, but I don't.

Mr. **Green**. Could I submit some other questions for the record?

Mr. **Traxler**. Of course. And I might say that we have a series of budget questions that we will submit to you for the record.

Mr. **Bromley**. I would be happy to try to respond, sir.

[The information follows:]

Questions for the Record Submitted by Congressman Bob Traxler

OBLIGATED BALANCES

Question. The budget requests $3,300,000 and 43 FTE for the Office of Science and Technology Policy in 1991. That is an increase of $471,000 and 4 FTE above 1990. In the program and financing schedule on page 11, the obligated balance at the end of the year increases from $1,045,000 in 1989 to $1,542,000 estimated for 1990, $1,730,000 estimated for 1991.

Why do you estimate an increase in the obligated balances at the end of 1990 and 1991?

Did OMB increase the obligated balance estimates or are these your original estimates?

Answer. The increase in the estimated level of obligated balances is the result of the application of the outlay spend-out rate formulas developed by the Congressional Budget Office and the Office of Management and Budget, and does not reflect any specific programmatic assumptions. Because the OSTP budget is increasing rapidly over this period, it is possible that the use of the historical average spend-out rate may not be accurate. However, we will not have a better estimate until the end of the fiscal year approaches.

FISCAL YEAR 1989 FTE LEVEL

Question. Last year your estimated 20 FTE in 1989. The actual 1989 FTE level was 12.

What caused the actual FTE level in 1989 to be so far below last year's estimate?

Answer. Due to delays in my appointment, until August 8, 1989, I was unable to appoint new staff members until the latter part of the fiscal year. This impacted on the Offices use of FTEs for FY 1989.

PERSONNEL COMPENSATION

Question. The object schedule on page 13 indicates $1,313,000 for full-time positions in 1990 and $1,789,000 in 1991.

Will the amount shown for personnel compensation in 1990 support 39 FTE? If not how many FTE can be supported with that dollar amount?

Can OSTP support a 43 FTE in 1991 with the funds requested?

Does your 1991 request for personnel compensation funds include the costs of the SES and January 1991 pay increases?

Answer. It is anticipated that the FY 1990 estimate will support 39 FTE in FY 1990. The Office plans that the funding requested for FY 1991 will fully support 43 FTE. OSTP, as did most agenices absorbed 50% of the costs associated with the SES and January 1991 pay increases.

EQUIPMENT

Question. Actual obligations in 1989 for equipment totaled $62,000. Last year, you indicated $5,000 for equipment in 1989. As I understand it, OSTP has undertaken a major ADP equipment purchase.

Is that correct?

What types of equipment were purchased in 1989?

Answer. Yes, we have undertaken steps toward ADP equipment purchases. During FY 1989 the following equipment was purchased to increase OSTP's efficiency and enhance communication:

IBM PS/2 Model 55 SX (10 ordered).

IBM PS/2 Model 80 (1 ordered).

COMPAQ 386S Model 84 (1 ordered).

COMPAQ 386/20E Model 110 (1 ordered).

Laserjet Series II Printed (5 ordered).

Laserjet Series II Printer with double tray (2 ordered).

All of the associate hardware and software required to arrange for the equipment to become functional, i.e., monitor, keyboard, async parallel cards, etc.

DETAILEES

Question. According to the justifications, you plan to greatly reduce the use of detailees in 1991.

How many detailees are currently at OSTP?

Do you anticipate reducing the number of detailees in 1990 below that level?

For the record, would you provide a table listing the cost per agency of reimbursable and non-reimbursable detailees in Fiscal Year 1989. A similar table can be found on page 38 of last year's hearings.

Answer. There are currently 12 detailees assigned to the OSTP at this time. It is anticipated that by the end of FY 1990, our use of detailees will be reduced.

The following chart is provided, at the Committee's request:

Agency	Reimbursable	Nonreimbursable	Total
Action	14,628.72	14,628.72	29,257.444
Agency for International Development	54,069.17	54,069.17	108,138.34
Central Intelligence Agency	16,162.202	———	16,162.50
Department of Commerce	13,138.00	13,138.00	26,276.00
Department of Defense	768.56	768.56	1,537.12

Agency	Reimbursable	Nonreimbursable	Total
Department of Energy	81,320.00	81,320.00	162,640.00
Department of Interior	17,789.57	17,789.57	35,579.14
National Institutes of Health	8,362.18	8,362.18	16,724.36
National Science Foundation	32,898.87	32,898.87	65,797.74
Office of Management and Budget	44,401.90	44,401.90	88,803.80
IPA Fairfax County	7,374.58	7,374.58	14,749.16
Total	[1] 290,914.05	274,751.55	565,665.60

[1] Rounded to $291,000.

Mr. TRAXLER. I want to commend you for your appearance this morning. It has been most enjoyable, and one of the things that we discover as we talk with agency personnel is that we learn something every day from them.

Mr. BROMLEY. Good.

Mr. TRAXLER. So, it has been most beneficial for us.

Mr. BROMLEY. Thank you for inviting me.

Mr. TRAXLER. Thank you.

Mrs. BOGGS. Thank you.

[Questions for the record and the justification follows:]

Questions for the Record Submitted by Congressman Louis Stokes

SCIENCE AND MATHEMATICS EDUCATION

Question. Yesterday, during the National Science Foundation Hearings, Chairman Traxler asked Dr. Shakhashiri about an observation he made in the record last year regarding the performance of American students in the areas of Science and Math. Dr. Shakhashiri comments related to the results of a 1988 International study of 13-year-olds conducted in 5 countries and 4 Canadian Provinces, in which U.S. students scored lowest among the 12 populations in math and the fourth lowest in science. He stated that: "The 13 year olds who were tested last year as part of this study will be in college in another four years, those of them who don't drop out first—and will be in the workforce in ten—those of them who end up well enough educated to get and hold a job. Looked at in those terms, the lack of preparation for further education and future employment that these American teenagers demonstrated is nothing short of frightening." In response to this observation, Chairman Traxler noted that "the problem at the pre-college level is worse than serious—it would seem like it is cataclysmic."

This subcommittee raised this issue with you last year. In your statement prepared for today, I am pleased to see that your office has created a new "Science, Mathematics and Engineering Education" committee to develop a framework for interagency coordination and collaboration. I understand you are working to have the Department of Education to become a part of the FCCSET Council, so as to better implement this program.

A. What efforts will be taken to remedy the severe education deficit affecting our students? Specifically, what steps will be taken to enhance the participation of women and minorities, who are seriously disadvantaged, yet who will have to provide much of the talent we will need in order to remain competitive.

In recent months, NSF released a report titled, "Women and Minorities in Science and Engineering." The report found that while some progress has been made, women and minorities remain woefully under represented. Women constitute about 50 percent of the population, but only 16 percent of the science and engineering. Moreover, Dr. Bloch of the NSF indicated yesterday, during hearings, that the numbers have reached a plateau and are starting to decline. Blacks who comprise almost 12 percent of the U.S. population make up 2.6 percent of the S/E workforce; Hispanics constitute over 7 percent of our population, but only constitute 1.8 percent of the S/E workforce.

B. The issue of science and math education and literacy is the last goal addressed in your testimony, while you state on page 6 of your testimony that the need for enhanced Research and Development is the Administration's "Chief Emphasis." Considering the current educational needs, and the projected demands of the next century, which is less than a decade away, do you think that science and math education at all levels should receive heightened priority in the administration's budget and objectives?

C. Considering the 1 out of 2 of all minority children live in poverty, what strategies will your office encourage, so as to help ensure that these children, who may be malnourished and struggling to deal with the many other problems associated with poverty will be able to grasp the complex theories needed to compete in the emerging markets.

Answer. The reason this country is so good at the graduate level and poor at the precollege level is that we sacrifice large numbers of students along the way, and an unacceptable proportion of those are women and minorities.

In December the Task Force on Women, Minorities, and the Handicapped in Science and Technology released its final report, "Changing America: The New Face of Science and Engineering." That report contains a number of goals for the nation and recommendations for the key players in American society that could increase the representation of women, minorities, and the handicapped in science and engineering. The OSTP convened the first meeting of the task force and endorsed its goals.

The Federal Coordinating Council for Science, Engineering, and Technology committee dealing with education will address this problem in the coming months.

B. Science and math education has received heightened priority in the administration's budget and objectives. The Administration's proposed increase of 27% in FY 1991 for science and mathematics education supported by the National Science Foundation, the Department of Education, the Department of Energy, NASA, and the National Institutes of Health is substantial. Funding in these five agencies would rise from $841 million to $1.06 billion. These funds support new and existing agency programs that target revitalization of mathematics, science, and engineering education to produce the technological workforce and scientifically literate population needed to maintain a globally competitive economy.

I am taking steps to establish a new FCCSET committee to deal with education and human resources. This new FCCSET committee will elevate consideration of math and science education priorities and activities within government in the months ahead. The objective of the Committee is to develop a truly integrated interagency effort in strengthening education in these fields at all levels; and develop and maintain a technologically literate work force.

C. The first of the National Education Goals, as announced by the President, and the Nation's Governors, is that "by the year 2000, all children in America will start school ready to learn." This led to a number of initiatives within the federal budget. A 36 percent increase over the 1990 level has been proposed for Head Start, and a doubling of funds has been proposed for Even Start.

Funds for Chapter 1 Local Education Agency and Concentration Grants are increased by $366 million, the largest Federal elementary and secondary education program for at-risk children. $401 million in budget authority for the proposed Educational Excellence Act.

Another National Education Goal, as announced by President Bush, is by the year 2000, US students will be first in the world in science and mathematics achievement.

My office will actively work to coordinate Federal math and science education activities across all agencies, and to make sure that those efforts specifically targeted toward poor children are taken into account in our overall strategy toward improving math and science literacy in this country.

BUDGET INCREASES FOR SCIENCE AND SPACE

Question. With recent developments across the globe particularly in Eastern Europe, steps are being taken to decrease the defense budget. President Bush, himself, in his State of the Union Address delivered last month, stated that he will reduce troops in Eastern Europe. And now that it finally appears that the defense budget will be reduced, we see that the Administration recommends tremendous increases in the areas of science and space. NASA has been designated for a 24 percent increase in FY 1991.

And, just last week it was reported that Admiral Truly is expected to create three new management positions to coordinate the lunar base and Mars expedition effort. Proposed candidates for two of the slots include officials who have worked at the Strategic Defense Initiative Organization (SDIO):

It appears that we are trading-in costly defense programs for costly space programs. The emphasis has changed to a degree, but the same contractors and smaller subcontractors will continue to be the primary beneficiaries of mega-buck contracts. This occurrence will make it very difficult for us to provide needed funding for many of those domestic programs funded by this subcommittee which have been neglected over the years.

A. How would you explain this redirection of funding, without a significant change in emphasis?

B. Considering that about 90 percent of NASA's budget is contracted out, isn't the Administration, in effect, making it clear that it prefers subsidized space activities, rather than subsidizing housing. HUD's budget provides no funding for any new low-income, housing units.

Answer. A. In developing its budget request for FY 1991, the Administration did not 'trade-off' funding in one category for funding in another. In fact, each Federal agency submitted to the Administration a proposed funding plan that was evaluated on its own merits. After all agency funding proposals had been through this evaluation and elimination process, the President reviewed the resulting programmatic requests to determine the areas of maximum effectiveness for new initiatives. Clearly, areas in which the Federal government, itself, is either the only consumer or the dominate consumer—such as defense and space—require relatively more support than areas where there are other players who also provide resources to support the work that needs to be accomplished.

B. This Administration believes that the investment in space activities for civilian, commercial and national security purposes, is a wise one. We are committed to a sustained, continuing and balanced program which advances US leadership in aeronautics and space. This program is one of the principal symbols of American technological and scientific prowess and will make highly significant contributions to our efforts toward building a better America. The goals of those activities include increasing our knowledge about our planet and our universe, helping to understand and to protect our global environment, enhancing US industrial competitiveness, and, at the same time, contributing in both tangible and intangible ways to this country's new initiatives in science, engineering and mathematics education.

I also want to point out that research and development (R&D) accounts for nearly 50% of the NASA budget. In the Administration's FY 1991 budget request for NASA, approximately 7.7 billion will support R&D and associated R&D facilities, an increase of 1.8 billion, or 35% over FY 1990. Within the total, funds will be available to complete some space science projects currently under development, to support ongoing longterm research and technology, to advance projects in space and aeronautics, and to initiate two major projects. Funding for the first initiative, Mission to Planet Earth, will begin the design and development of the Earth Observing System (EOS) and a support program of earth probes. The EOS and earth probe programs will provide long-term data on changes in the global environment. The second major initiative relates to human exploration of space. In FY 1991 the Exploration Activity will focus on developing technologies required to support human exploration beyond Earth orbit. The goal of both the individual technology projects and the systems technology projects is to develop the ability to do reliably, safely and economically everything that the challenges on the space frontier demand and thus, to establish a robust American presence in space.

EDUCATION OF FOREIGN NATIONALS

Question. The chairman yesterday and on several other occasions has made reference to the fact that currently 40–50 percent of Ph.D's in the United States are held by Foreign Nationals.

A. Considering some of the recent developments in Eastern Europe, to what extent does the elimination of the Berlin Wall provide a gateway to the West, for aspiring Eastern European scientists and engineers? To put it another way, will steps be taken to allow these students to obtain training in the U.S.?

B. Historically, many immigrants have found refuge in America. That is a characteristic which distinguishes our country from others. However, keeping in mind current trends, several well-respected academicians have suggested to me that rather than effectively addressing the special needs of our minority and female populations, there is the possibility that efforts will be pursued which will use foreign talent as a substitute to training our own. What are your thoughts on this issue?

Answer. A. The United States has a long history of training scientists and engineers from around the world without discrimination. We are proud of that heritage and do not intend to take steps to change it. Many countries of Eastern Europe have fine institutions of higher education specializing in science and engineering and their students would bring special skills to the United States should they chose to study here. As restrictions are eased, we would expect that more and more East European students would seek opportunities to study in the United States, and as with other countries, we will welcome them. To facilitate exchanges of researchers, the United States has entered into science and technology agreements with a number of countries of eastern Europe including, Hungary, Poland, and Yugoslavia. In addition, NSF has agreements with these countries and with Czechoslovakia, and Bulgaria.

B. We are concerned about the lack of our own students going into mathematics and science education. We need to work to improve our precollege educational system and to increase the number of American students studying math and science. Attracting and retaining many more women and minorities in science and engineering is an important part of that strategy. One of the highest priorities of this Administration is the retention of women and minorities in these fields.

Questions for the Record Submitted by Congressman Silvio Conte

DECADE OF THE BRAIN

Question. Last year, Congress enacted legislation identifying the 1990s as the Decade of the Brain. As you know, the Office of Science and Technology Policy was identified by this Subcommittee as the lead agency to coordinate government-wide activities pertaining to the Decade of the Brain. I note with disappointment that the Office has not visably promoted such activities during the past year. This is unfortunate, given the opportunities presented by the recent explosion of knowledge about brain physiology and function to seek the causes and cures of diseases and disorders affecting the brain and central nervous system; to come to an understanding of basic processes like learning and behavior; and to apply such knowledge to such areas as artificial intelligence and informational technology. Why hasn't the Office taken a more active role pursuing activities related to the Decade of the Brain, especially given the clear direction provided by this subcommittee to do so? What plans does the Office have to promote the Decade of the Brain in the coming year?

Answer. One of the first activities undertaken by Dr. James B. Wyngaarden, after his confirmation on November 18, 1989, as Associate Director for Life Sciences, Office of Science and Technology Policy (OSTP), was to recruit Dr. Roger Porter, Scholar In Residence, Division of Medical Research, Association of American Medical Colleges, to chair a working group to develop a plan for government-wide activities pertaining to the Decade of the Brain. A policy analyst was specifically recruited for the Life Sciences Division, OSTP, to coordinate these efforts, and to serve as executive secretary of the working group. This working group is composed of Deputy Directors of the eight National institutes of Health and the Alcohol, Drug Abuse and Mental Health Administration Institutes that sponsor brain related research, as well as representatives from other relevant federal agencies—the National Science Foundation, the Department of Defense, and the Veterans Administration.

The working group is enthusiastically addressing plans to build upon the remarkable advances in the neurosciences in celebration of the Decade of the Brain. So far, the group has generated a list of eight specific science elements through which the various organizations might contribute to create an integrated program. These topics include addiction, aging, behavior and mental disorders, communication and sensory disorders, rehabilitation and restoration of function, as well as education, learning and memory.

The working group will have its third meeting in April, when plans will be further developed regarding the launching of Decade's activities. The working group plans to reach out to Federal agencies, the scientific community and voluntary health agencies for the advice and participation in planning these activities. The working group is also considering the possibility of creating a ten-year research plan for the neurosciences. Naturally, all these plans will be discussed with the Subcommittee before they are finalized.

When the President signs the formal proclamation declaring the 1990s the Decade of the Brain, a press release on the government's plans for the Decade will be released.

OSTP also will act as a central clearinghouse for information on the various activities related to the Decade of the Brain, planned by the Federal government as well as the private sector. OSTP has already begun gathering information on the activities underway or planned by private foundations, the National Academy of Sciences, as well as those sponsored by Federal agencies. Also, OSTP members are working with representatives of private sector groups with interests in the Decade, including the National Coalition for Research in Neurological Disorders.

Questions for the Record Submitted by Congressman Bill Green

U.S. Educational System

Question. At the graduate level in many technical disciplines we seem heavily dependent on foreign students to get the doctorate and teach in our graduate schools. How specifically do you propose to overcome that?

Answer. American graduate education is the best in the world, and as long as we maintain that level we expect that the best of the foreign students will want to come here to study. Many foreign students remain in the U.S. following the receipt of their degrees, and it is a good thing for us that they do. We rely on these individuals for an important part of our scientific, technological, and economic strength.

The large fraction of foreign students in science and engineering programs does not mean that there are too many foreign students in this country. Rather, it means that too few Americans are choosing to enter these fields. If we are to build up the proportion of American students in science and engineering, we must concentrate of improving the educational system that produces those students, as well as the reward system in our economy that attracts good students into science and technology.

We need to work to improve our precollege system. One necessity in building up our educational system is that we begin to attract and retain many more women and minorities in science and engineering.

The Administration is proposing a more than 27% increaase over FY 1990 for science and mathematics education supported by the National Science Foundation, the Department of Education, the Department of Energy, NASA, and the National Institutes of Health. Funding in these five agencies would rise from $841 million to $1.06 billion. These funds support new and existing agency programs that target revitalization of mathematics, science, and engineering education to produce the technological workforce and scientifically literate population needed to maintain a globally competitive economy.

Through the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), OSTP is developing a fremework for interagency coordination and collaboration for mathematics, science, engineering and technology education. The goal is to develop an effective and appropriate role for the federal government in support of the states, localities, and universities as they participate in strengthening science and technology education at all levels.

Question. I don't want to turn this into a forum to debate the treatment of Chinese students here, but I do perceive that they, like previous immigrants, can add much to our science establishment. I hope the Administration's concerns with Beijing will not prejudice the Chinese students. Many of these students are in science disciplines. It is not enough to refrain just from deporting them; they need funds to exist. Has Beijing cut them off? I gather from the NSF that we are funding them to a degree. What do we need to do to deal with this group?

Answer. Talented Chinese students, like other foreign students pursuing research and educational opportunities, enhance research capabilities of our universities. Since the June 3–4 Tiananmen Square incident, the Chinese Government has instituted a five year work requirement before Chinese scholars are allowed to pursue research opportunities overseas. While this will diminish in the short-term the number of Chinese students coming to the United States, many of the students here are seeking and obtaining longer term support and staying in the United States longer than their predecessors.

NSF, HHS, DOE and other federal agencies involved with the support of university research activities fund many of these students through grants to private investigators in these universities who in turn support Chinese and other foreign researchers as students and postdoctoral fellows. Following Tiananmen, moreover, NSF made funds available for up to one year to any private investigator supporting a Chinese researcher whose term of stay would expire before June 4, 1990. Nearly 200 Chinese students and research associates received approximately $1.8 million in support under this program.

It is important to note, that Chinese students, as well as other foreign and U.S. students—particularly in areas of mathematics, science and engineering—can and will find support through ongoing research at their institutions to support their stays in the United States.

OSTP ASSOCIATE DIRECTOR FOR SOCIAL SCIENCE

Question. I know you've talked about the importance of the social sciences to the science policy in our country. I had heard that you * * *? the appointment of an Assistant Director for the Social Science at OSTP. Will this happen? Do you have sufficient funds in FY 90 to make it happen? If not, does your FY 91 request contain enough money to make it happen?

Answer. I do feel that a strong, vibrant social science research community is important for this country, and that it is especially important for the science policy in our country. This means specifically that we need appropriate staff support for dealing with social science issues. I am searching for a suitable candidate to take on an Assistant Directorship in OSTP in the area of social sciences. This individual would also work closely with Associate Director Thomas Ratchford in OSTP's education activities. While it will be difficult to fit this position into the approved OSTP roster, I believe that the area is of such importance that we must make a very real effort to include if effectively within our office.

FISCAL YEAR 1991 BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
BUDGET SUBMISSION
FY 1991

CONTENTS

		PAGE
I.	GENERAL STATEMENT	1
II.	SUMMARY OVERVIEW	3
III.	APPROPRIATION LANGUAGE	10
IV.	EXPLANATION AND JUSTIFICATION OF CHANGES BY OBJECT CLASS FOR FY 1991	16
V.	SUMMARY TABLES	
	Summary of Changes from FY 1990 to FY 1991	18
	Summary of Budget Authority by Object Class	19
VI.	A SUMMARY OF ACCOMPLISHMENTS IN FY 1989 BY THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY	21

I. GENERAL STATEMENT

Executive Office of the President
Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was created by the National Science and Technology Policy, Organization, and Priorities Act of 1976 (Public Law 94-282). The Office serves as a source of science and technology expertise for the President and other organizations within the Executive Office of the President provides for coordination and policy analysis of research and development programs of the Federal government; and with the Office of Management and Budget, conducts reviews and analyses of research and development programs of the Federal government.

Major activities of the OSTP include the following:

- Advise the President on scientific and technological issues involved in areas of national and international concern.
- Advise the National Security Council on the scientific and technological considerations related to national security and international issues.
- Develop and review with the Office of Management and Budget proposed Administration budgets for Federal R&D programs.
- Provide general leadership and coordination of research and development programs of the Federal government through the FCCSET Committee structure; analyze problems and developments in science and technology affecting more than one Federal agency and recommend policies and procedures for dealing with there areas.
- Encourage a stronger partnership between Federal research agencies, State and local governments, and the scientific community.
- Provide Executive Branch views and perspectives in areas regarding science and technology policy to the Congress.

- FROM 1982-1989 THE WHITE HOUSE SCIENCE COUNCIL ADVISED THE DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY ON ISSUES IN SCIENCE AND TECHNOLOGY SPECIFIC CONCERN TO THE PRESIDENT AND THE NATION, AND ON JANUARY 19, 1990, THE PRESIDENT ESTABLISHED A NEW ADVISORY BODY, THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY ("PCAST"). THE PCAST WILL NOW ADVISE THE PRESIDENT ON ALL AREAS OF SCIENCE AND TECHNOLOGY OF CONCERN TO THE NATION. THE DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY WILL SERVE AS CHAIRMAN OF THIS COUNCIL.

II. SUMMARY OVERVIEW

THE TOTAL FY 1991 BUDGET REQUEST OF $3,300,000 FOR THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP) WILL SUPPORT AN ESTIMATED 39 PROFESSIONAL STAFF AND SUPPORT MEMBERS.

THE FY 1991 REQUEST PROVIDES FOR FOUR CONFIRMED ASSOCIATE DIRECTORS -- THE FULL NUMBER AUTHORIZED IN THE 1976 ENABLING LEGISLATION. THE FOUR AREAS OF RESPONSIBILITIES ARE: POLICY AND INTERNATIONAL SCIENCE AND TECHNOLOGY; INDUSTRIAL TECHNOLOGY; LIFE SCIENCES; AND PHYSICAL AND ENGINEERING SCIENCES. IN ADDITION THE FY 1991 REQUEST WILL PROVIDE FOR A SMALL CADRE OF ASSISTANT DIRECTORS AND SENIOR POLICY ANALYSTS TO ASSIST THE ASSOCIATE DIRECTORS. THE PROFESSIONAL STAFF WILL BE GENERALISTS, RATHER THAN SPECIALISTS. THIS IS ESSENTIAL, GIVEN THE NUMBER OF ISSUES ADDRESSED BY OSTP, AND THE CHANGES IN EMPHASIS FROM YEAR TO YEAR. THIS STAFFING ASSUMES USE OF DETAILEES ONLY UNDER UNUSUAL CIRCUMSTANCES WHERE NO OTHER ALTERNATIVE IS AVAILABLE.

THE FY 1991 REQUEST INCLUDES $135,000 FOR SUPPORT OF THE PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY (PCAST): $60,000 FOR THE SALARY OF THE EXECUTIVE DIRECTOR, $15,000 FOR PRINTING COSTS FOR REPORTS GENERATED BY PCAST; AND $60,000 FOR TRAVEL AND SUBSISTENCE FOR MEMBERS OF PCAST. THE PCAST WILL BE A VERY ACTIVE GROUP, WITH MONTHLY PLENARY MEETINGS, AND AN EXTENSIVE SUBCOMMITTEE, PANEL AND WORKING GROUP SUBSTRUCTURE. THIS WILL ENTAIL SIGNIFICANTLY INCREASED COSTS FROM PREVIOUS YEARS.

THE BUDGET REQUEST FOR FY 1991 IS 16.7-PERCENT, OR $471,000, ABOVE THAT CURRENTLY APPROPRIATED FOR FY 1990. HOWEVER, INCREASE 4.8-PERCENT, OR $135,000, IS IN SUPPORT OF THE PRESIDENT'S COUNCIL OF ADVISORS FOR SCIENCE AND TECHNOLOGY. THE REQUEST PROVIDES A BASE OF SUPPORT WHICH WILL ALLOW OSTP TO FULFILL ITS GROWING RESPONSIBILITIES FOR COORDINATION OF THE R&D POLICY OF THE ADMINISTRATION. THIS ESSENTIAL LEVEL OF COORDINATION IS HIGHLY LABOR INTENSIVE, AND SHOULD NOT BE DELEGATED OUTSIDE THE EXECUTIVE OFFICE. THE EXISTING RESPONSIBILITIES OF OSTP INCLUDE THE FOLLOWING:

- Direction of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). This requires an intensive level of participation, coordination, and guidance by OSTP staff in the numerous working groups of the various FCCSET committees.

- Interagency coordination, under FCCSET, of science and technology issues to be incorporated in negotiated agreements with foreign countries.

- Recommendations to the President on current major issues of science and technology policy; direction of, and participation in, interagency coordination on such issues, as appropriate. These activities require a high level of participation and interaction by OSTP in the numerous coordinating groups within the Executive Office of the President.

- Anticipation of new science and technology issues, or other issues with a significant science and technology component; advice to the President and initiation of interagency coordination on such issues, including technical findings or other actions, as appropriate.

- Coordination of the President's Council of Advisers on Science and Technology findings with interagency findings in appropriate areas of concern to the President and his Advisors.

- Coordination with the Office of Management and Budget of the Administration's budget request to Congress for science and technology.

- Preparation of reports, in accordance with legislative direction, including for 1990:

  A. Analysis of the balance between defense and non-defense research and development,

  B. Report detailing the steps that the Department of Education and the National Science Foundation are taking to cooperate more readily on improving the coordination of math, science and engineering education, and

c. Report describing OSTP views on the principle scientific questions in global change research, that are in greatest need of attention by the Congress; and how the existing inter-agency Committee on Earth Sciences research strategy plans to answer these questions.

The responsibilities of OSTP have grown in recent years with growth in importance of science and technology in government policy and in the general affairs of this nation. In addition, the role of the OSTP and of the Science Advisor has been recast to a more dominant position, and will require a correspondingly increased workload. Specifically:

- The Director has been named to the newly created position of Assistant to the President for Science and Technology. He has also been asked by the President to chair a new advisory group called the President's Council of Advisors on Science and Technology (PCAST).

- The Director of OSTP will now be a member of the Economic Policy Council, the Space Council and the Domestic Policy Council. In addition, the Director will be taking a very active role in the newly created Council on Competitiveness chaired by the Vice President, where the Director or his designee will be chairing a working group on biotechnology. Effective participation in these groups will require additional staff to support the Director of OSTP.

- OSTP will be assume additional responsibilities in diverse areas including: science and mathematics education; the environment; and technology policy particularly as it relates to global competitiveness.

- The Director of OSTP would activate the Joint Telecommunications Resources Board to advise the President during a non-wartime emergency on national security and emergency preparedness telecommunications and would exercise the President's wartime telecommunications emergency functions when required.

- The enhanced role of the Science Advisor -- the Assistant to the President for Science and Technology -- and the expanded mission and augmented role of PCAST will inevitably create greater demands on the staff and on required staff time.

Given the high workload expected from FY 1991 and beyond, the requested level of support is fully in keeping with current budgetary constraints. In view of the significant leverage that can be exerted by coordination of Science and Technology Policy within the Executive Office on the overall coherence and effectiveness of the research and development conducted within the nation, this is a cost-effective program that Congress can support.

Executive Office of the President
Office of Science and Technology Policy

BUDGET OVERVIEW

(IN THOUSANDS OF DOLLARS)

	FY 1989	Estimated FY 1990	Estimated FY 1991	Net Change FY 90 - 91
Budget Authority:				
Appropriation	$1,574	$2,829	$3,300	$471
Employment:				
FTP	11	33	39	6
FTE	12	39	43	4

Executive Office of the President

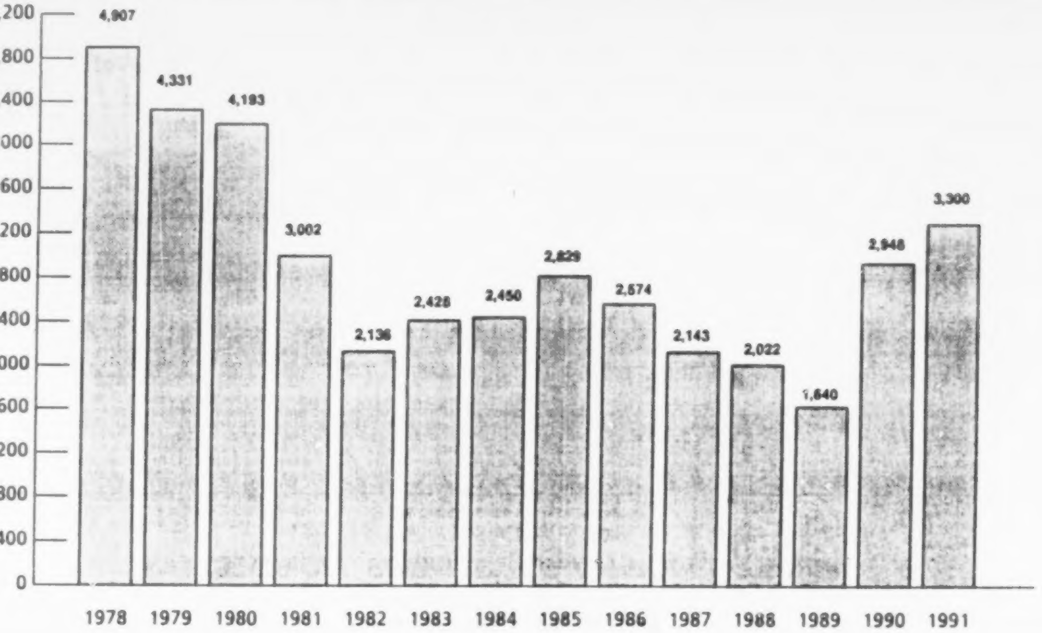
Office of Science and Technology Policy

HISTORICAL SUMMARY OF APPROPRIATIONS

In Constant Dollars'

Fiscal Years 1978 - 1991

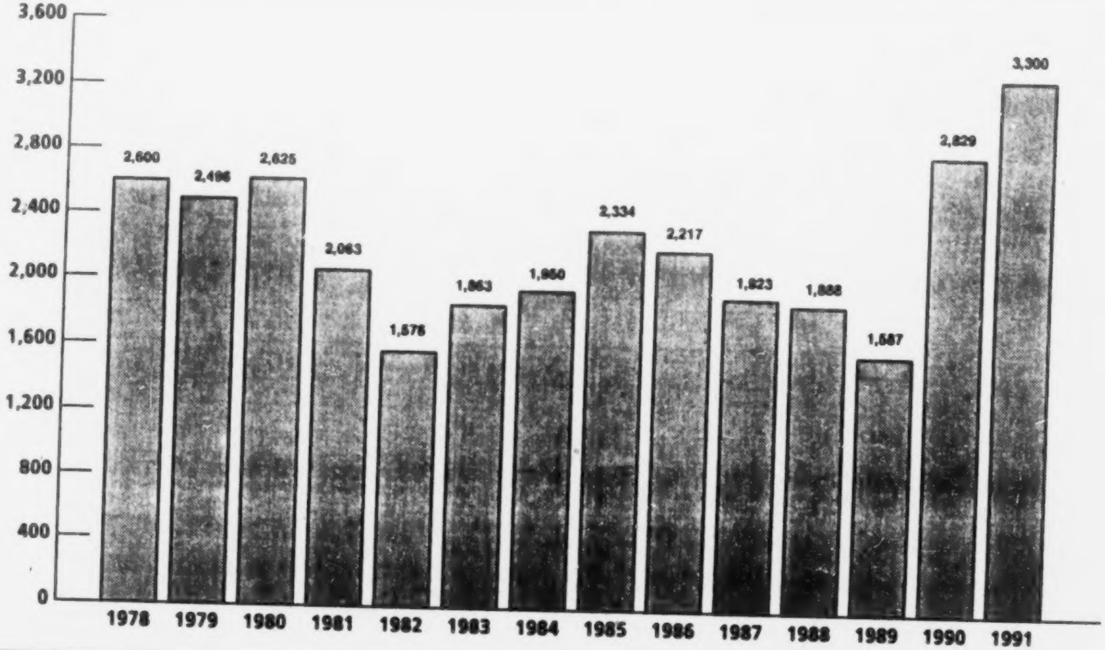
(IN THOUSANDS OF DOLLARS)



Executive Office of the President
Office of Science and Technology Policy

HISTORICAL SUMMARY OF APPROPRIATIONS

Fiscal Years 1978 - 1991
(IN THOUSANDS OF DOLLARS)



III. APPROPRIATION LANGUAGE

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

SALARIES AND EXPENSES

FOR NECESSARY EXPENSES OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY, IN CARRYING OUT THE PURPOSES OF THE NATIONAL SCIENCE AND TECHNOLOGY POLICY, ORGANIZATION, AND PRIORITIES ACT OF 1976 (42 U.S.C. 6601 AND 6671), HIRE OF PASSENGER MOTOR VEHICLES, SERVICES AS AUTHORIZED BY 5 U.S.C. 3109, NOT TO EXCEED $1,500 FOR OFFICIAL RECEPTION AND REPRESENTATION EXPENSES, AND RENTAL OF CONFERENCE ROOMS IN THE DISTRICT OF COLUMBIA [$2,829,000] $3,300,000. PROVIDED, THAT THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY SHALL REIMBURSE OTHER AGENCIES FOR NOT LESS THAN ONE-HALF OF THE PERSONNEL COMPENSATION COSTS OF INDIVIDUALS DETAILED TO IT. (DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, DEPARTMENT OF VETERANS AFFAIRS, INDEPENDENT AGENCIES APPROPRIATIONS ACT, 1990.)

STANDARD FORM 300
July 1964, Bureau of the Budget
Circular No. A-11, Revised.
300-101

Office of Science and Technology Policy
Salaries and Expenses

Program and Financing (in thousands of dollars)

Identification code 11-2600-0-1-802	19 89 actual	19 90 estimate	19 91 estimate
Program by activities:			
00.01 Direct program: Administrative support	1,574	2,829	3,300
01.01 Reimbursable program	—	—	—
10.00 Total obligations	1,574	2,897	3,300
Financing:			
11.00 Offsetting collections from: Federal funds	—	—	—
25.00 Unobligated balance lapsing	13	—	—
40.00 Appropriation	1,587	2,897	3,300
40.00 Reduction pursuant to P.L. 101-144	—	- 45	—
40.00 Reduction pursuant to P.L. 99-177	—	- 23	—
43.00 Appropriation (adjusted)	1,587	2,829	3,300
Relation of obligations to outlays:			
71.00 Obligations incurred, net	1,574	2,829	3,300
72.40 Obligated balance, start of year	986	1,045	1,542
74.40 Obligated balance, end of year	-1,045	-1,542	-1,730
77.00 Adjustments in expired accounts	- 176	—	—
90.00 Outlays	1,339	2,332	3,112

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

PROGRAM AND PERFORMANCE

THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP) PROVIDES ADVICE TO THE PRESIDENT CONCERNING POLICIES IN SCIENCE AND TECHNOLOGY AND ON THE UTILIZATION OF SCIENCE AND TECHNOLOGY IN ADDRESSING IMPORTANT NATIONAL PROBLEMS. THE OSTP OPERATIONS INCLUDE SUPPORT TO OTHER EXECUTIVE OFFICE OF THE PRESIDENT ORGANIZATIONS ON ISSUES WITH SCIENCE AND TECHNOLOGY CONSIDERATIONS; REVIEW AND ANALYSIS, WITH THE OFFICE OF MANAGEMENT AND BUDGET, OF RESEARCH AND DEVELOPMENT BUDGETS FOR ALL FEDERAL AGENCIES; COORDINATION OF RESEARCH AND DEVELOPMENT PROGRAMS OF THE FEDERAL GOVERNMENT; COORDINATION OF THE IMPLEMENTATION OF A NUMBER OF IMPORTANT INTERNATIONAL SCIENCE AND TECHNOLOGY AGREEMENTS; AND OTHER ACTIVITIES NECESSARY TO CARRY OUT THE DUTIES, FUNCTIONS, AND ACTIVITIES DESCRIBED IN PUBLIC LAW 94-282, THE NATIONAL SCIENCE AND TECHNOLOGY POLICY, ORGANIZATION, AND PRIORITIES ACT OF 1976.

STANDARD FORM 300
July 1964, Bureau of the Budget
Circular No. A-11, Revised.
300-101

Office of Science and Technology Policy
Salaries and Expenses

Object Classification (in thousands of dollars)

Identification code 11-2600-0-1-802		1989 actual	1990 estimate	1991 estimate
Direct obligations:				
Personnel compensation:				
11.1	Full-time permanent	411	1,213	1,789
11.3	Other than full-time permanent	47	30	30
11.5	Other personnel compensation	35	40	40
11.8	Special personal services payments	291	337	128
11.9	Total personnel compensation	784	1,620	1,987
12.1	Personnel benefits: Civilian	81	325	410
21.0	Travel and transportation of persons	69	100	104
22.0	Transportation of things	3	3	3
23.1	Rental Payments to GSA	370	497	514
23.3	Communications, utilities, and miscellaneous charges	117	152	158
24.0	Printing and reproduction	13	6	20
25.0	Other services	35	51	56
26.0	Supplies and materials	40	43	43
31.0	Equipment	62	32	5
99.9	Total obligations	1,574	2,829	3,300

STANDARD FORM 300
July 1964, Bureau of the Budget
Circular No. A-11, Revised.
300-101

Office of Science and Technology Policy
Salaries and Expenses

Personnel Summary

Identification code 11-2600-0-1-802	19 89 actual	19 90 estimate	19 91 estimate
Total number of full-time permanent positions	11	33	39
Total Compensable workyears:			
Full-time equivalent employment	12	39	43
Full-time equivalent of overtime and holiday hours	1	1	—

STANDARD FORM 306
July 1968, Bureau of the Budget
Circular No. A-11, Revised.
[illegible]

OFFICE OF SCIENCE AND TECHNOLOGY POLICY
Salaries and Expenses

DETAIL OF PERMANENT POSITIONS

11-2600-0-1-802	19 89 actual	19 90 estimate	19 91 estimate
Executive Level II	1	1	1
Executive Level III	2	3	3
Subtotal	3	4	4
ES-4	1	4	4
ES-3	1	1	1
Subtotal	2	5	5
GS-15	0	1	2
GS-14	0	3	3
GS-13	2	2	2
GS-12	1	6	9
GS-10	1	3	3
GS-8	0	7	9
GS-7	1	1	1
GS-5	1	1	1
Subtotal	6	24	30
Total permanent positions	11	33	39
Unfilled positions/end of year	4	—	—
Total permanent employment/end of year	15	33	39

IV. EXPLANATION AND JUSTIFICATION OF CHANGES BY OBJECT CLASS FOR FY 1991

Executive Office of the President
Office of Science and Technology Policy
(in thousands of dollars)

I. Increases to Maintain Current Services and Requests Levels $3,300

FY 90	FY 91		CHANGES 90-91
$1,945	$2,397	Personnel compensation and benefits This funding amount will provide for a staffing level of 39 full-time permanent (FTP) and 43 full-time equivalent (FTE).	$ 452
$ 100	$ 104	Travel and transportation of persons An increase of $4,000 is a balance of two factors. In FY 1990 OSTP staff anticipated significant travel to foreign countries for negiotiation of S&T agreements. Little such travel will occur in FY 1991, but resources are required for the new Presidential panel, PCAST. The increase will provide base travel expenses for the OSTP staff ($44,000) and also for increased travel costs associated with the President's Council on Science and Technology ($60,000).	$ 4
$ 3	$ 3	Transportation of things No increases are anticipated in this category. The requested funding level is sufficient to cover the cost of commercial courier services and transportation companies.	$ 0
$ 497	$ 514	Rental Payments to GSA (SLUC) Additional space is being acquired for FY 1991 over FY 1990 due to the increased staffing level.	$ 17

FY 90	FY 91		
$ 152	$ 158	Communications, Utilities, and Miscellaneous Charges	$ 6
		Our request will provide for OSTP's area commercial utilities, including: telephone service (AT&T and FTS); GSA after-hour utilities; postage; and the cost of data lines and other communication links with other agencies and with the science community at large.	
$ 6	$ 20	Printing and reproduction	$ 14
		These funds provide for government and commercial printing requirements, including publication charges for the Federal Register. The increase provides anticipated costs for publications by the President's Council on Science and Technology ($14,000).	
$ 51	$ 56	Other services	$ 5
		This line item will provide for normal maintenance costs of reproduction and ADP equipment and the cost of access to commercial data based systems.	
$ 43	$ 43	Supplies and materials	$ 0
		OSTP's use of traditional office supplies has decreased while the need for specialized office supplies such as off-the-shelf software and ADP supplies has increased. Thus, we anticipate this category to remain nearly constant in FY 1991.	
$ 32	$ 5	Equipment	$ (27)
		In an effort to increase OSTP's efficiency and enhance communication, a major drive will be completed during FY 1990 to purchase ADP equipment. Our equipment will allow OSTP to reduce dependence upon limited personnel resources and allow increased compatibility with the EOP information network. The requested amount reflects anticipated minimum costs required to maintain these systems during FY 1991.	
$2,829	$3,300	Total all object classes	$ 471

Executive Office of the President
Office of Science and Technology Policy

SUMMARY OF CHANGES FROM FY 1990 TO FY 1991 BY OBJECT CLASS

(IN THOUSANDS OF DOLLARS)

	Increases	Decreases	
FY 1990 BUDGET AUTHORITY			*$2,829*
CURRENT PROPOSED FY 1991			*$3,300*
Personnel compensation	367	0	
Personnel benefits	85	0	
Total compensation and benefits	452	0	
Travel and transportation of persons	4	0	
Transportation of things	0	0	
Rental payments to GSA	17	0	
Comm., util., and misc. charges	6	0	
Printing and reproduction	14	0	
Other services	5	0	
Supplies and materials	0	0	
Equipment	0	27	
Total	498	27	
Net Increase/Decrease	471		

Executive Office of the President
Office of Science and Technology Policy

SUMMARY OF BUDGET AUTHORITY BY OBJECT CLASS

FY 1989–1991

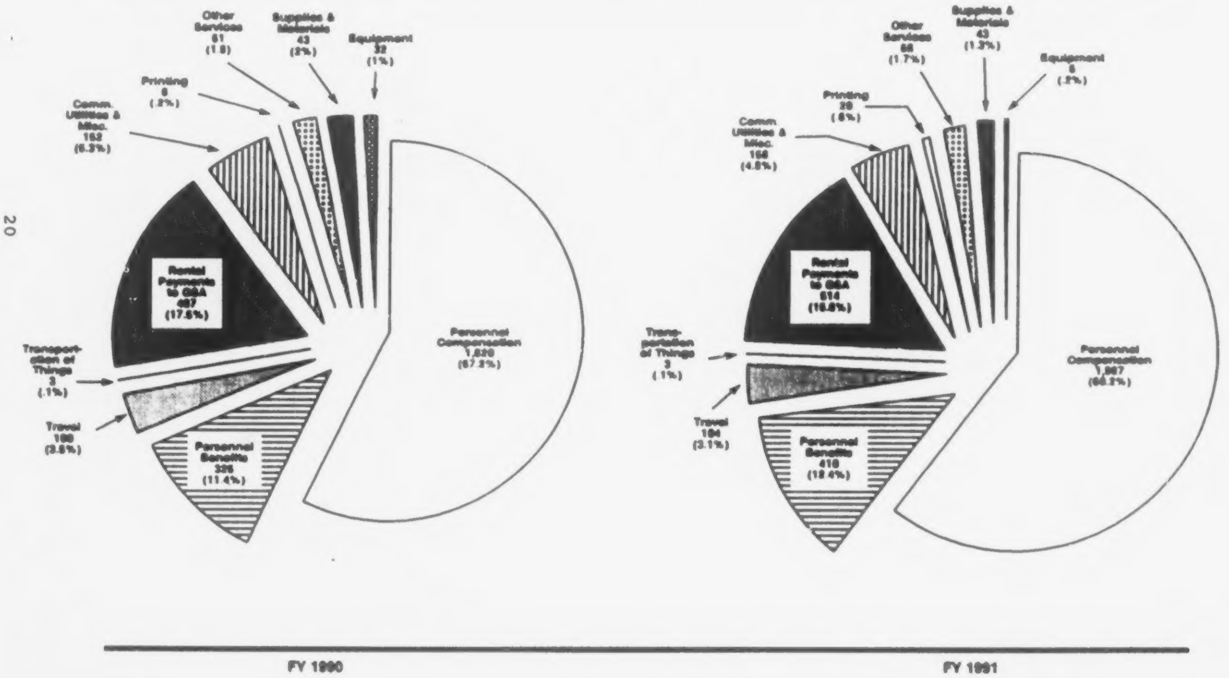
BUDGET OVERVIEW
(in thousands of dollars)

	Actual FY 1989	Estimated FY 1990	Estimated FY 1991	Net Change FY 90 - 91
Personnel compensation:				
Full-time permanent	411	1,213	1,789	576
Other than full-time permanent	47	30	30	0
Other personnel compensation	35	40	40	0
Special personal services payments	291	337	128	(209)
Total personnel compensation	784	1,620	1,987	367
Personnel benefits: Civilian	81	236	410	86
Total compensation and benefits	865	1,945	2,397	452
Travel and transportation of persons	69	100	104	4
Transportation of things	3	3	3	0
Rental payment to GSA	370	497	514	17
Comm., util., and misc., chgs.	117	152	158	6
Printing and reproduction	13	6	20	14
Other services	36	51	56	5
Supplies and materials	40	43	43	0
Equipment	62	32	5	(27)
Subtotal, direct obligations	1,574	2,829	3,300	471
Reimbursable obligations	0	0	0	0
Lapse	13	0	0	0
Budget Authority	1,587	2,829	3,300	471

Executive Office of the President
Office of Science and Technology Policy

FUNDING BY OBJECT CLASS

Fiscal Years 1990 – 1991
(IN THOUSANDS OF DOLLARS)



SUMMARY OF ACCOMPLISHMENTS IN FY 1989 BY THE OFFICE OF SCIENCE AND TECHOLOGY POLICY

CONTENTS

PAGE

SECTION A. NATIONAL SCIENCE AND TECHNOLOGY POLICY

1 POLICY ON GLOBAL CHANGE 24
2 FOREIGN POLICY AND INTERNATIONAL SCIENCE 24
3 TECHNOLOGY POLICY 25

SECTION B. REORGANIZATION IN ANTICIPATION OF EXPANDED ACTIVITY 25

SECTION C. COORDINATION OF FEDERAL SCIENCE AND TECHNOLOGY ACTIVITIES

1 FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY (FCSSET) 26
2 BIOTECHNOLOGY SCIENCE COORDINATING COMMITTEE 26
3 COMMITTEE ON EARTH SCIENCES 27
4 COMMITTEE ON LIFE SCIENCES 27
5 INTERAGENCY HUMAN SUBJECTS COORDINATING COMMITTEE 28
6 COMMITTEE ON MATERIALS 28
7 RADIATION RESEARCH AND POLICY COORDINATION COMMITTEE 28
8 COMPUTER RESEARCH AND APPLICATIONS COMMITTEE 29
9 COMMITTEE ON INTERNATIONAL SCIENCE, ENGINEERING, AND TECHNOLOGY 29
10 SCIENCE AND TECHNOLOGY REPORT 29
11 OTHER ACTIVITIES 29

SECTION D. COMPETITIVENESS 30

1 U.S. COMPETITIVENESS IN THE SEMICONDUCTOR INDUSTRY 30

PAGE

SECTION E. INTERNATIONAL SCIENCE 30

1 U.S.-SOVIET BLOC SCIENCE AND TECHNOLOGY RELATIONSHIP 31
2 JAPAN 31
3 WESTERN EUROPE 31
4 INDIA 32
5 PEOPLE'S REPUBLIC OF CHINA 32
6 OTHER ACTIVITIES 32

SECTION F. NATIONAL SECURITY

1 NATIONAL SECURITY STUDIES 32
2 DEFENSE BASIC RESEARCH 33
3 ARMS CONTROL VERIFICATION 33
4 EMERGENCY PREPAREDNESS PLANNING AND TELECOMMUNICATIONS POLICY 33
5 TECHNOLOGIES RELEVANT TO NATIONAL DEFENSE 33
6 TECHNOLOGY TRANSFER 34
7 OTHER ACTIVITIES 34

SECTION G. SPACE

1 NATIONAL SPACE POLICY 34
2 SPACE SCIENCE 35
3 SPACE STATION 35

SECTION H. SCIENCE AND TECHNOLOGY RESOURCES

1 NATIONAL MEDAL OF SCIENCE 35
2 PRESIDENTIAL AWARDS FOR EXCELLENCE IN SCIENCE AND MATHEMATICS TEACHING 36
3 SCIENCE APPOINTMENT CANDIDATES 36

SUMMARY OF ACCOMPLISHMENTS

FY 1989

A REPORT TO CONGRESS

The Bush Administration's science and technology policy is designed to increase the contribution of science and technology to the national goals of improved economic competitiveness and a strong national defense. This has been and will continue to be reflected in annual Federal budgets.

The activities of the Office of Science and Technology Policy in support of that policy include: 1) participating in the formulation of national policy on issues that involve science and technology; 2) providing access to authoritative science and technology information and expert scientific and engineering advice for the President, Federal officials, and Congress as input to the decision-making process; 3) coordinating research and development efforts by agencies of the Federal Government, to maximize the return on the nation's investment in R&D and to insure that these resources are used efficiently and appropriately.

The broad goals are to ensure that the U.S. continues to lead the world in research and technology, to maintain the science and technology base that supports the U.S. competitive position in international markets, to apply science and technology to the resolution of domestic social concerns, to support national security through a strong capability for national defense, and to promote increased international understanding through scientific cooperation.

The activities and accomplishments of the Office of Science and Technology Policy during fiscal year 1989 are summarized in the following pages.

A. NATIONAL SCIENCE AND TECHNOLOGY POLICY

A.1 POLICY ON GLOBAL CHANGE

To insure the development of a comprehensive and forward-looking U.S. policy on global change based upon sound scientific principles and consistent with strong economic growth, the President in FY 1989 established a new Working Group on Global Change under the Domestic Policy Council. Because the new working group is chaired by OSTP Director D. Allan Bromley, OSTP has been intimately involved in the process of formulating U.S. policy on global change. The Working Group set in motion a series of studies on: (1) Economic costs of responding to global change; (2) Private sector activities and issues; (3) Legal precedents for international agreements and conventions. The working group also began compiling a summary of all U.S. Government activities on global change and examining the various responsibilities and mandates of the different agencies with regard to global change.

In addition, OSTP has been involved in the planning for a White House Conference on Scientific and Economic Research on the Environment, which is to be hosted by the President and attended by international delegations composed of the chief science official, chief economic official, and chief environmental official from each nation. The focus of the meeting will be to advance the quality and understanding of the analytical tools for confronting environmental problems. The anticipated result would be a common integrated approach for all nations to use in future negotiations on environmental problems. It is anticipated that the Conference will take place in the spring of 1990.

Finally, OSTP has played a coordinating role in the development of a comprehensive, focused U.S. research and development program for global change, through the Committee on Earth Sciences of the Federal Coordinating Council on Science, Engineering, and Technology (see Section C.2 below).

A.2 FOREIGN POLICY AND INTERNATIONAL SCIENCE

As the world becomes increasingly interdependent--economically, militarily, and environmentally--the linkage between science and technology issues and foreign policy objectives has grown. During FY 1989, OSTP made efforts to ensure that international science and technology cooperation became more integral parts of U.S. foreign relations and that science and technology aspects were adequately considered in the development of U.S. foreign policy. This has resulted in improved review and coordination of science and technology issues into the agenda for state visits and for Economic Summits. OSTP worked closely with the National Security Council, State Department, and appropriate U.S. Government technical agencies, as well as the nation's scientific and engineering communities, to assure the success of such visits and the Summits in terms of U.S. foreign policy goals and other national interests. OSTP's role includes participation in the initial planning stages, and in some cases, in the events themselves and in follow-up actions to implement Presidential policy decisions or initiatives resulting from the visit.

At the same time, international science and technology has assumed an importance that is much greater today than in the past. The Bush Administration has sought to encourage international participation in a number of large, world class science projects currently under development, including the Superconducting Super Collider, Space Station Freedom, and the human genome project. In FY 1989, OSTP worked actively with the Department of State and the responsible technical agencies to bring about this international participation. OSTP also began to develop a long-range strategy designed to provide a more comprehensive approach toward international cooperation in large science projects.

Finally, OSTP sought in FY 1989 to strengthen international cooperation in science and technology and to coordinate the many bilateral science and technology agreements between the United States and other nations (see Section E, below).

A.3 TECHNOLOGY POLICY

In light of world events and the changing economic and political scene, the Bush Administration considers it extremely important to review existing policies that affect the development of commercially important technologies and that restrict their movement in international trade. Accordingly, in FY 1989, OSTP and OMB formed a small working group to review the technology policy and recommend improvements. The group has interviewed more than 50 individuals from government, industry, academia, and other private sector organizations to obtain a wide range of views on this subject. The goal of the review is to modify these policies as necessary to meet the needs of the 1990s.

The project is continuing and it is anticipated that it will present its recommendations in FY 1990.

B. REORGANIZATION IN ANTICIPATION OF EXPANDED ACTIVITY

In FY 1989, OSTP was expanded and reorganized to carry out its missions more efficiently. The President nominated D. Allan Bromley as the new Director of OSTP and also appointed him Assistant to the President for Science and Technology. The President also announced his intention to nominate for confirmation all four Associate Directors called for in the establishing legislation, P.L.94-282. These Associate Directors will focus on physical science and engineering, life science, technology, and policy and international science.

In FY 1989, the President also announced his intention to create a President's Council of Advisors on Science and Technology to consist of 12 distinguished individuals from the private sector and to be chaired by the Director of OSTP, and to meet frequently with the Council. It is anticipated that the first meeting will occur in February, 1990.

C. COORDINATION OF FEDERAL SCIENCE AND TECHNOLOGY ACTIVITIES

C.1 FEDERAL COORDINATING COUNCIL FOR SCIENCE, ENGINEERING, AND TECHNOLOGY (FCCSET)

The FCCSET was established in 1976 by P.L. 94-282 to deal with science and technology policy issues affecting more than one federal agency. It is chaired by the Director of OSTP. During FY 1989, the active committees were:

Biotechnology Science Coordinating Committee
Committee of Earth Sciences
Committee on Life Sciences
Interagency Human Subjects Coordinating Committee
Committee on Materials
Radiation Research and Policy Coordination Committee
Committee on Computer Research and Applications
Committee on International Science, Engineering, and Technology

In FY 1989, the Director of OSTP began planning for the restructuring and revitalization of FCCSET at the direction of the President. It is anticipated that this reorganization will be accomplished early in FY 1990 with the elimination of inactive committees and the incorporation of others into a limited number of committees that will span the spectrum of science and technology in a more appropriate manner. It is also anticipated that new mechanisms will be instituted to improve communication within FCCSET and reporting by the committees to FCCSET, thus improving the usefulness of the Council as a body for coordinating federal science and technology efforts and for resolving science and technology policy issues.

C.2 BIOTECHNOLOGY SCIENCE COORDINATING COMMITTEE

The Biotechnology Science Coordinating Committee (BSCC) is responsible for providing the opportunity for interagency science coordination and guidance, and for the exchange of information to ensure that U.S. biotechnology regulatory policy is based on a solid scientific foundation. In FY 1988, the BSCC asked the National Academy of Sciences to evaluate scientific information pertinent to making decisions about the introduction of genetically modified microorganisms and plants into the environment. The report, Field Testing Genetically Modified Organisms: Framework for Decisions, was released in FY 1989 and has proven to be a scholarly, useful document. Discussions are under way to extend this study to include transgenic fish and livestock. The NAS recommendations the basis for development of an initial draft paper on the scope of regulations for small-scale field trials. In FY 1989, the BSCC also conducted scientific reviews of proposed biotechnology rules and commented on several other documents and proposed committees.

C.3 COMMITTEE ON EARTH SCIENCES

During FY 1989, the Committee on Earth Sciences (CES) developed a comprehensive, coordinated research plan for global change designed to increase the overall effectivness and productivity of Federal research efforts aimed at understanding the Earth as a global system. In January 1989, the CES submitted a research strategy report entitled Our Changing Planet: A U.S. Strategy for Global Change Research to Congress along with President Reagan's budget. A few months later that report was also endorsed by President Bush. In July, 1989, the CES published Our Changing Planet: the FY 1990 Research Plan. This report, which is expected to be updated annually, outlines a priority framework for focusing and integrating the interagency research efforts to ensure that they meet the objectives described in the research strategy report. The research program was developed in close cooperation with the National Academy of Sciences and a number of international earth science research institutions and programs.

The CES had a number of other active subcommittees in FY 1989, including a Committee on Groundwater Research, which published Federal Groundwater Science and Technology Programs, and a Committee on Natural Disaster Reduction.

C.4 COMMITTEE ON LIFE SCIENCES

The Committee on Life Sciences (CLS) provides a central forum for overall interagency policy coordination, guidance and the exchange of information regarding the federal programs, policies, and procedures relating to life sciences, including such areas as human genome research, plant sciences, international, regulatory, and policy aspects of biotechnology, and risk assessment.

The Human Genome Subcommittee of the CLS serves as a forum for the exchange of Human Genome-related program plans, coordination of research, and discussion of legislative and international issues. Four agencies (NIH, DOE, USDA, and NSF) and the Howard Hughes Medical Institute serve as permanent representatives on the subcommittee. The International Biotechnology Subcommittee (IBS) has taken up the functions of the original Domestic Policy Working Group on Biotechnology while the CLS as a whole considers biotechnology policy issues. In FY 1989 the IBS developed U.S. positions for international meetings and continued to monitor international and regulatory issues in biotechnology. Also in FY 1989, a working group was formed to assess the needs for a data base of information on environmental issues associated with release of genetically modified organisms. The U.S.-Japan Subcommittee (USJS) was established in FY 1989 to coordinate the activities of Federal agencies in regard to scientific cooperation with Japan. Areas of interest for joint research and specific proposals were developed and transmitted to Japanese counterparts under the U.S.-Japan Science and Technology Agreement through the USJS.

C.5 INTERAGENCY HUMAN SUBJECTS COORDINATING COMMITTEE

A model policy for the protection of human subjects in research was published by the Committee for comment in the Federal Register in June 1986. A final notice of proposed rulemaking on the model policy was published in the Federal Register early in FY 1989. Subsequently the Committee developed regulations to implement the model policy. During FY 1989 the regulations were agreed to and signed by 17 department heads, but the Committee awaits the signature of one final Department, after which the document will be sent of OSTP for promulgation.

C.6 COMMITTEE ON MATERIALS

The principal vehicle for OSTP coordination of materials policy and planning is the Committee on Materials (COMAT). In FY 1989, OSTP and the Committee took the lead role in working with the staff of the National Critical Materials Council and a task force of experts from throughout the Government and private industry on the first report of the 5-year National Action Plan on superconductivity R&D required by Public Law 100-697. The report was issued in December, 1989.

In FY 1989, the Committee was also active in helping to formulate U.S. policy positions for international meetings and in coordinating Federal research and development efforts in superconductivity, robotics, and data standardization. The superconductivity subcommittee of COMAT produced a report, Federal Research Programs in Superconductivity, that surveys agency programs in superconductivity research. The Versailles Advanced Materials and Standards subcommittee coordinated 14 projects designed to accelerate data standards for characterizing new materials. The composite subcommittee published a report, Composite Databases for the 1990's, which outlines the relationships between the many kinds of databases needed in research, production, and use of advanced composite materials.

C.7 RADIATION RESEARCH AND POLICY COORDINATION COMMITTEE

The Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) is the principal coordinating mechanism to to address radiation issues of national interest. In FY 1989, there were 54 meetings of the Committee and its eight active policy subpanels. These include: Radioepidemiological Tables; Naturally Occurring and Accelerator-Procured Radioactive Materials; Scientific Basis for Radiation Protection Standards; High-LET Radiation; Pre-disaster Planning for Human Health Effects Research; Ionizing Radiation Risk Assessment BEIR IV; Occupational Radiation Protection Research; and Use of BEIR V and UNSCEAR in Risk Assessment. The Committee produced several reports in FY 1989, including Report of the Ad Hoc Planning Group which sets forth a plan to address radiation issues important to the nation.

C.8 COMPUTER RESEARCH AND APPLICATIONS COMMITTEE

The Computer Research and Applications Committee exists to coordinate agency programs in advanced computing and applications and to assess the status of the U.S. supercomputer industry. In FY 1989 the Committee began developing a detailed program plan for coordination of agency high performance computing programs. The resulting plan is contained in the report, The Federal High Performance Computing Program, delivered to the Congress on September 8, 1989.

C.9 COMMITTEE ON INTERNATIONAL SCIENCE, ENGINEERING, AND TECHNOLOGY

The Committee on International Science, Engineering, and Technology exists to coordinate and implement the President's policy and priority programs in international science and technology cooperation to advance broad national goals. A new area of activity in FY 1989 for the Committee was the establishment of a working group to investigate changes in European science and technology as a result of the economic integration of the European Community in 1992 and the implications for the U.S. scientific and engineering community.

C.10 SCIENCE AND TECHNOLOGY REPORT

In cooperation with the National Science Foundation, OSTP published in January 1989 the Science and Technology Report covering the years 1985 through 1988, as requested by Chairman Roe of the House Science, Commerce and Space Committee. Final print of this document was distributed in May 1989.

C.11 OTHER ACTIVITIES

In FY 1989, OSTP participated in the activities of the the Arctic Research Commission, whose purpose is to establish and implement (by means of an Interagency Arctic Research Policy Committee) a national arctic research program plan. The mandated biennial revision of the Plan, submitted to the President in July 1989, demonstrated several interagency cooperative programs on sea ice/ecosystem and land/atmosphere interactions. The Arctic Research Commission continues to issue annual and special reports containing guidance and recommendations to agencies.

OSTP also began planning and coordinating government-wide initiatives for the Decade of the Brain, established by a joint resolution of the Congress and signed by the President to recognize the dramatic increase in knowledge about the brain and its disorders and the formidable challenges of the future. Activities of the decade are intended to increase public awareness and understanding of the brain and its disorders and involve the scientific community in exploring promising directions in research on the central nervous system.

D. COMPETITIVENESS

Since the reorganization of OSTP, the Director of OSTP is a member of the Council on Competitiveness chaired by the Vice-President. In FY 1989, OSTP began to develop a presentation on biotechnology for the Council on Competitiveness.

D.1 U.S. COMPETITIVENESS IN THE SEMICONDUCTOR INDUSTRY

OSTP has controlling responsibility for implementation of P.L. 100-418, which created the National Advisory Committee on Semiconductors (NACS). The purpose of NACS is to "devise and promulgate a national semiconductor strategy, including research and development, the implementation of which will assure the continued leadership of the United States in semiconductor technology."
NACS held its first meeting on January 11, 1989 and has had five subsequent meetings in FY 1989. NACS issued an interim report to the public in 1989 on consumer electronics/high definition television and the report A Strategic Industry at Risk.

The Administration has held several policy forums to discuss possible Federal involvement in the areas of advanced video technology and high definition television. OSTP participated in the Secretary of Commerce industry/government committee, the USTR-led EPC working group on HDTV, and the Department of Commerce-led working group preparing presidential policy options.

OSTP leads and chairs meetings of an inter-agency working group examining the role of the Administration in x-ray lithography, a proposed technology for defining small feature size semiconductors for the mid-1990's.

E. INTERNATIONAL SCIENCE

During FY 1989, OSTP helped to coordinate and participated in a number of multilateral and bilateral efforts to improve science and technology infrastructure around the world and to strengthen science and technology cooperation. OSTP also helped to review U.S. participation in, and funding of, the International Institute of Applied Systems Analysis (IIASA), which resulted in a presidential decision to provide funding for IIASA, with the expectation that significant changes in the charter and research program will be negotiated during FY 1990.

In compliance with Title V of the Foreign Relations Authorization Act of 1979, OSTP transmitted to Congress in early 1989 the President's 1988 Report on Science, Technology, and American Diplomacy, which reports on U.S. Government policies and activities in international science and technology as an adjunct to U.S. foreign policy objectives. The President's transmittal letter to the Congress serves as a key statement of the Administration's policies and thrusts in international science and technology.

E.1 U.S.-SOVIET BLOC SCIENCE AND TECHNOLOGY RELATIONSHIP

In FY 1989, after lengthy negotiation in which OSTP played an active role, the U.S. and the Soviet Union concluded a new Basic Science Agreement, expanding cooperation in a wide range of basic sciences fields while ensuring proper protection of material, information and equipment classified for national security purposes and ensuring adequate protection of intellectual property rights. OSTP also participated in the development of U.S. Government proposals and positions for the 1989 Bush-Gorbachev meeting. The meeting resulted in the adoption of two OSTP-proposed, multilateral environmental initiatives which will be carried out in 1990.

Developments in Eastern Europe have provided an impetus to OSTP and other technical agencies to continue to expand their science and technology cooperation with this region. For example, OSTP participated in planning and negotiation of a new science and technology umbrella agreement with Hungary aimed at stimulating cooperation in a wide range of fields.

E.2 JAPAN

In FY 1989, under OSTP direction, the first meeting of the Joint High Level Advisory Panel met in Tokyo pursuant to the head of government U.S.-Japan Science and Technology Agreement. The Panel identified a number of research fields, including global change and new materials, for possible cooperative efforts. OSTP coordinated an interagency review of the input provided by the Panel and, where appropriate, took steps to implement recommended measures. OSTP also planned and participated in the second Joint Working Level Committee meeting in April 1989. The meeting provided an opportunity for counterparts from the two countries to discuss potential cooperative efforts and to plan workshop and study teams.

Federal Coordinating Council for Science, Engineering and Technology (FCCSET) Committees, under OSTP leadership, met throughout the year to discuss and develop joint research topics. In this effort, they focused their activities on identifying areas in which the Japanese have a clear technological lead.

OSTP participated in formulating a U.S. Government response to the Japanese Human Frontiers Science Program, a new Japanese government effort to expand their international basic research efforts in the life sciences.

E.3 WESTERN EUROPE

In FY 1989, OSTP participated in meetings of the U.S.-E.C. High Technology Work Group which focused on publically funded research and development programs and biotechnology regulations. These meetings have helped to provide an important step toward understanding the differences in the two R&D systems and the nature of the development and implementation of important regulatory standards that affect U.S. industry in the European market.

E.4 INDIA

In FY 1989, OSTP continued to provide policy guidance for the Presidential Science and Technology Initiative intended to improve the overall relationship between the United States and India.

Negotiations between the two countries to protect and allocate appropriately and equitably the intellectual property resulting from joint research and development continued in FY 1989 but negotiations broke down in a disagreement over the level of patent protection in India and distribution of rights. As a result, OSTP directed the Department of State to develop a mechanism to screen all future Science and Technology cooperation with India for intellectual property rights considerations.

E.5 PEOPLE'S REPUBLIC OF CHINA

OSTP participated in an Executive Secretary's meeting in the People's Republic of China (PRC) in May 1989. The meeting was designed to prepare the two sides for the scheduled sixth meeting of the Joint Commission on Science and Technology which was to have celebrated the 10th anniversary of S&T cooperation. The Joint Commission meeting was cancelled following the Tienanmen Square incident. OSTP is continuing to monitor low-level S&T exchanges between the two countries.

E.6 OTHER ACTIVITIES

The Director of OSTP gave the keynote address at the Second ASEAN Science and Technology Week in Manila, Philippines, in support of stronger commitments to collaborate on science and technology with those countries. OSTP also led an effort to initiate discussions for an Science and Technology agreement with the Philippines and a Science and Technology Initiative with Mexico, both aimed at strengthening science and technology cooperation. OSTP also participated in discussions with Brazil, Spain and Indonesia on improved science and technology cooperation.

F. NATIONAL SECURITY

F.1 NATIONAL SECURITY STUDIES

In FY 1989, OSTP participated in efforts aimed at resolving critical scientific and technical issues and provided for the drafting of position and issue papers for use by the National Security Council, the OMB, and participating agencies. OSTP was also involved in reviews on modernization of U.S. strategic systems and continued to follow these efforts closely and to provide scientifically-based observations both to the NSC staff and to the Air Force.

F.2 DEFENSE BASIC RESEARCH

Through a series of technology-based briefings by the services, the Defense Advanced Research Projects Agency, and Office of the Secretary of Defense, OSTP maintained familiarity with the goals, the objectives, and the management of the various defense programs that sponsored laboratory and university research in FY 1989. The Director of OSTP interceded with the Secretary of Defense and the Office of Management and Budget on behalf of defense funding of basic research and continued to monitor the funding and management of the University Research Initiative.

F.3 ARMS CONTROL VERIFICATION

In FY 1989, OSTP continued to work with the Department of Defense and the Arms Control and Disarmament Agency, as well as the U.S. negotiating teams, on the technical aspects of verification capabilities and requirements. OSTP also provided technical expertise and review in the area of nuclear testing verification capabilities and requirements, in support of U.S.-USSR negotiations on a threshold test ban treaty.

F.4 EMERGENCY PREPAREDNESS PLANNING AND TELECOMMUNICATIONS POLICY

By Executive Order, the Director of OSTP, is assigned the responsibility for managing the nation's telecommunications resources during wartime and non-wartime national crises and emergencies. In FY 1989 this responsibility was met by constant planning, training, and supervision and by maintaining a high state of readiness. OSTP also participated actively in emergency telecommunications planning and in formulating telecommunications policy through membership on steering groups and advisory boards, interaction with the National Security Council and OMB, and maintaining a working relationship with the National Communications Systems and its members.

F.5 TECHNOLOGIES RELEVANT TO NATIONAL DEFENSE

OSTP participated during FY 1989 in a number of efforts by the military services aimed at articulating the principles, the practical applications, and the evaluation techniques applicable to command, control, communications, and intelligence (C3I) and to the disruption of these essential military activities (counter-C3I). OSTP was also active in FY 1989 in examining the implications of submarine technology development for anti-submarine warfare and in interacting with the Navy and its laboratories on this subject.

OSTP continued to play a role in assessing the potential and the possible pitfalls associated with smart missile concepts. Two co-joint papers have were published by OSTP in FY 1989 and have received wide circulation within the Department of Defense.

In FY 1989, OSTP continued to monitor the progress in stealth and in the applied sciences that makes possible the drastic reduction of observables. These include techniques applicable to radar cross-section reduction, to optical and infrared signature control and the attenuation of acoustic signatures.

F.6 TECHNOLOGY TRANSFER

OSTP assisted the National Security Council in redefining the President's policy on U.S. export controls during FY 1989. The principal activities involved U.S. export control policy toward the People's Republic of China, West-West trade, COCOM, and the review of technology transfer requirements and policies formulated by government departments. As an example, OSTP played a central role in coordinating government-wide activities to finalize technical guidelines for U.S. industry to use in the potential sale of a direct broadcast satellite to the People's Republic of China.

F.7 OTHER ACTIVITIES

OSTP maintained close interest and involvement in the planning, technology development, and analysis that addresses the military's ability to receive and utilize intelligence collected by national technical means. Issues involving requirements generation, hardware development, downlink and processing centers, and doctrinal approaches to utilizing the intelligence have received attention throughout FY 1989.

OSTP also maintained involvement with the government's program for applying advanced technology to counter the threat of terrorism through a senior technology oversight panel which reviews candidate projects to insure that projects are selected with full understanding of the technological issues and risks involved.

G. SPACE

G.1 NATIONAL SPACE POLICY

Following the establishment of the National Space Council in March 1989, the Director of OSTP was designated by the President as statutory member of the Council. The OSTP participated in the Council's activities including: the revision of U.S. policy on Landsat development and operations; the updating of National Space Policy; the reaffirmation by the President of the long-range goals of manned presence beyond the Earth's orbit; and the ongoing review of other space issues.

During FY 1989, OSTP was intimately involved in the National Space Council's review of the National Aerospace Plane program and the decision to delay deployment and to redefine and continue the program as an R&D effort. The Director of OSTP is a member of the National Aerospace Plane Steering Committee. OSTP maintains a close overview of the program and continues to work closely with Congress, the Space Council, OMB, the Program office, and participating agencies to ensure the success of this vital national technology program.

G.2 SPACE SCIENCE

OSTP continued to work with OMB, NASA, and the science communities on space science issues during FY 1989 in order to maintain a vigorous space science program. OSTP has also worked closely with the scientific community and the NASA advisory committees to establish mechanisms that assure that advice and recommendations from the scientific community are utilized by the agency for the process of cross-disciplinary ranking of scientific programs is utilized by the agency.

One of OSTP's major responsibilities in FY 1989 was the launch approval of the GALILEO mission as directed in NSC-25. GALILEO was launched successfully carrying two radioisotope units containing Pu-238 as its long-term power source. Development began on plans for the launch of the next nuclear-powered satellite in FY 1990.

G.3 SPACE STATION

As a result of an internal program cost review undertaken by NASA, the agency developed revised cost estimates for Space Station Freedom which substantially exceeded the original estimates. OSTP worked closely with OMB, NSC, and NASA to develop revised Space Station capabilities, schedules, and costs. An independent review of the Space Station Program was performed by the National Research Council's Committee on Space Station on a schedule permitting incorporation of any revised program scope in future year budget requests. After a shortfall in appropriations for the FY1990 budget, OSTP participated in a station rescoping and realignment of current international participation in this Presidential Initiative.

H. SCIENCE AND TECHNOLOGY RESOURCES

H.1 NATIONAL MEDAL OF SCIENCE

In the Fall of 1989 the President, in a White House ceremony, awarded 19 National Medals of Science and 8 National Medals of Technology; the nation's highest honors for achievement in mathematics, science and engineering, and technology. OSTP received recommendations made by the President's Committee on the National Medal of Science and served as the lead agency for these awards within the Executive Office of the President.

H.2 PRESIDENTIAL AWARDS FOR EXCELLENCE IN SCIENCE AND MATHEMATICS TEACHING

In 1989 the President greeted the recipients of the Presidential Awards for Excellence in Science and Mathematics Teaching at a White House ceremony. OSTP serves as the lead agency within the Executive Office of the President and works with the National Science Foundation in planning the event. The award was established by President Reagan in 1983 and represents the highest honor that any mathematics or science teacher can receive. The teachers are nominated by their peers with screening by a distinguished panel of educators and scientists whose recommendations were submitted to OSTP by NSF. The awards are presented annually to science and mathematics teachers selected from across the nation, two from each state, the District of Columbia, and Puerto Rico. Not only do these awards focus national attention on the importance of precollege science and mathematics education, they also encourage increased local support and contributions from industry.

H.3 SCIENCE APPOINTMENT CANDIDATES

OSTP continues to work with the Office of Presidential Personnel to identify highly qualified candidates for a range of top-level science appointments. These have included all the Presidential appointments to the National Science Foundation, the National Science Board, and key positions in the National Aeronautics and Space Administration, Department of Energy, Department of Commerce, Department of Defense, and Environmental Protection Agency. OSTP has also helped select appropriate, scientifically qualified personnel for the numerous committees, boards, and commissions set up by the President or Congress.

WITNESSES

Page

Bloch, Erich 1
Bromley, D.A 551
Bye, R.E., Jr 1
Clutter, Mary 1
Corell, Robert 1
Fenstermacher, Jeff 1
Good, Mary 1
Green, Richard 1
Shakhashiri, Bassam 1
Sundro, Linda 1
Toye, Sandra 1
White, John 1
Wilkniss, Peter 1
Wilson, Kent 1
Wulf, William 1

INDEX

National Science Foundation

Page

Antarctic Programs 118-125-126-127
  Antarctic Support Contractor Selection 128
  Continuing Need for South Pole Station 118
Astronomy 72
BBS 85
Basic Research 68
Bloch's Tenure at NSF 2
Budget Request 25
Centers versus Individual Investigators 61
Chinese Students Studying in U.S 60
CISE Directorate 88-90
  John von Neumann Center 86
DOD and Global Change 95
Domestic and International Cooperation 27
Doubling of NSF Budget 78
Earthquake Safety 101
Eastern Europe 70
Eastern European Development 69
Economic Competitiveness Overseas 77
Education 64
  Budget for Precollege Education 24
  Precollege and Undergraduate Education 22
  Precollege Science and Math Education 24
  Precollege Education 63
  Public School Systems 60
Education and Research and LIGO 73
EPSCoR 66
ERC 90-92
Foreign Participation 65
GEOSCIENCES 105
  Arctic Research 109
  Global Change—Global Warming 105
  Global Warming 106
  Ocean Sciences 106-107
  NSF Support for Faculty Salary 109
Global Change Data Management 93-94
Groups and Centers 23
History of NSF Budget 27
Icebreaker 71
IIASA 70
Initiatives for Economic Competitiveness 26
Introduction of Persons Around the Table 3

Page

- LIGO 74
- LIGO and Education and Research 74
  - Major Themes Comparison 22
  - Minorities and Women 57
- MPS 110
  - Astronomy 110
  - Astronomy-Telescope at Green Bank 111
  - Astronomy Telescopes 112-113-114
  - Mathematical and Physical Sciences 110
  - Priorities 115
  - Priority Setting for Major Research Equipment 116
- NSF Administrative Expenses: PD&M 141
  - Total Administrative Expenses of the Foundation 141
  - PD&M 143
- NSF Budget Request 2
- NSF as a Catalyst 25
- NSF and NIH Award Sizes 62
- NSFNET 88
- NSF Relocation 143
- Non-U.S. Citizen Doctorates 139
  - Appendix table 2-13 S/E Doctorates of Non-U.S. Citizens, by Visa Type: 1978-88 140
- Priority of Major Research Equipment Increase versus Science Education Increase 117
- Program Development and Management 28
- Questions Submitted by Chet Atkins 159
  - Sewage Treatment 161
  - Eastern Europe 162
- Questions Submitted by Lindy Boggs 147
  - EPSCoR and 1992 Plan 147
  - Role of EPSCoR Committees and Their Rates 148
- Questions Submitted by Jim Chapman 156
- Questions Submitted by Silvio Conte 165
  - Clean Up Plans 173
  - Coordination of Environmental Compliance Report 175
  - Funding for Section 5 H.R. 3977 168
  - Mineral Prospecting 172
  - National Environmental Policy Act 169
  - NSF and Environmental Laws 170
  - Precautions Against Oil Spills 175
  - Regulatory Expense 168
  - Regulatory Oversight of Tourism 168
  - Retrograde of Antarctic Waste 174
  - Tourism and Environmental Regulation 167
  - User Fees for Regulating Tourism 171
- Questions Submited by Lawrence Coughlin 102
  - NSB Report 103
  - NSF Educational Programs 104
  - Recruiting and Retaining Highly Qualified Employees 102
- Questions Submitted by Bill Green 134
  - Conflict-of-Interest Rule 135
  - Earthquake Hazard Reduction Program 134
  - Inspector General 136
  - NSF Support for Research in Superconductivity 134

Page
Questions Submitted by Jerry Lewis 96
  Earthquake Funding 96
  Nonaclonal Antibodies 98
Questions Submitted by Alan Mollohan 150
  Budget Write-up for R&RA and SEE 153
  Comparison of Staff Increases to Budget Increases 155
  Distinction between Research and Education 151
  Funding Patterns 154
  Level of Funding for Undergraduate Education 152
  New Building for SEE 154
Remarks of Dr. Good 5
  Written 5
  Oral 12
Research and Facilities 23
Research Facilities Program 117
Research Program 68
SEE Directorate 128–129
  Graduate Fellowships 132
  Multiagency Education Initiatives 132
  Science Education Outreach in the Community 132
  Science and Engineering Education 78
STC 85
Summary 145

Testimony of Mr. Bloch:

  Written 30
The Pipeline Issue 80–83
  Estimated Impact of $10 Million Budget Increment on Support of NS&E Personnel by Selected Federal Agencies 84
  Participation Rate for 22-year-olds in NS&E Bachelor's Degrees 81
Two-year Appropriations 144
U.S. Engineering & Scientific Workforce 59

View from NSB:

  The State of U.S. Science and Engineering 16
Women and Minorities 56
Women and Minorities in EPSCoR States 65

Office of Science and Technology Policy

Associate Director for Social Sciences, OSTP 607
Biography 570
Budget Increases for Science and Space 603
Civilian and Defense R&D 598
Conclusions 566
Cooperation with the Congress 572
Cost Estimates 574
Decade of the Brain 605
Detailees 601
Distribution of Federal Support for Education 581
Earth Observing System (EOS), The 595
Education in the United States 576, 606
Education of Foreign Nationals 604
Equipment 601
Federal Coordinating Council for Science, Engineering, and Technology, The 576
Federal Laboratory Roles in Education 586
Federal R&D Budget 561

Page
Fiscal Year 1991 Budget, Office of Science and Technology Policy 608
FTE Level, Fiscal Year 1989 601
Global Change 565
Industry-Academic Interactions 583
International Institute for Applied Systems Analysis 595
International Science and Technology 565
Life Sciences 564
Mega Projects—The Superconducting Super Collider, The Question of 572
Moon-Mars Initiative, The 591
National Air and Space Plane Program, The 590
Obligated Balances 600
Office of Science and Technology Policy 571
OSTP Budget Summary 567
OSTP/OMB Cooperation 557
Personnel Compensation 601
Priorities 561
Priorities in Large Scale Science 588
Recent OSTP Accomplishments 559
Science and Technology for Economic Growth 562
Science and Technology for National Security 564
Science Education 599
Science, Mathematics, and Engineering Education 566, 602
Scientific Priorities 597
Statement 551, 556
Technology Policy 584
Technology Transfer 586
Women and Minorities in Science 578

○